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Impact of Cultural Features within Enugu Urban Environment on the Quality of Streams in Nyaba Tropical Watershed of Southeast Nigeria

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Abstract: This investigation is conducted in Nyaba drainage basin, to examine impact of cultural elements within Enugu urban environment on the quality of streams in the basin. Samples of stream water and solid waste leachate were collected from 25 sub catchment areas of the basin and subjected to laboratory analysis of the biological characteristics. Field investigation of the stream velocity, width, depth, discharge, and flow variety in the sub catchments was also conducted Land use, water utilities, waste generation and management were also examined. The effect of solid waste disposal on the microbiological quality of the stream water was discovered to be the overall strongest factor of the 6 final components affecting water quality of streams in Nyaba river basin. The researcher therefore recommends a redirection of present efforts from water treatments focusing on microbiological quality surveillance as well as regulating the cultural characteristics with the aim of achieving sustainable solid waste disposal practice in the Enugu urban environment to restore and protect the ambient stream water quality in Nyaba catchment area.
Keywords: Cultural elements, urban environment.

INTRODUCTION

A catchment area can be defined as the whole of the land and water surface contributing to the stream flow at a particular stream or river cross section. In other words, a catchment area is a basin drained by a single river system.

The water and land area of a catchment system contribute to the quality and quantity of a stream at a particular stream cross section [1-4]. When urbanization takes place in the catchment area or part of it, the catchment area is said to be urbanized. Therefore in the present work, all such terms like urban watershed [5, 2] urban basin [2] and urban catchment system [6, 7] refer to urban catchment area.

The process of expanding urban environment has been taking place for more than 6000 years in some places [8]. Its pace has also increased markedly since the beginning of the nineteenth century, probably because urban areas are regarded as the loci and engine of development in world economies [9, 8, 10, 11].

The Census Bureau of the USA has also pointed out that in an urban area; a municipal authority provides local government services such as sewage treatment, infrastructure, utilities, crime prevention, and fire protection [12, 11]. An urban environment or urbanized area has also been defined from the view point of population statistics as an area with at least one huge center with a minimum of 50,000 persons and the surrounding area with a population density exceeding 625 persons per square kilometer (1,000 persons per square mile) [13, 11].

At the initial stages of urban development, population density was comparatively low and the carrying capacity of the urban environment was such that it could contain and the ecosystem was at near dynamic equilibrium position [11]. The introduction of industrialization increased the rate of urbanization and coupled with the activities of the urban man, worsened the situation with the result that today, most developed urban environments in the drainage basins have found themselves in very critical conditions of environmental pollution, especially surface water pollution [8, 14]. Nowhere are the surface water quality changes more dramatic than those observed when a catchment area undergoes urban development.

Certain site factors were *ab initio* responsible for the choice of these urban settlements and they comprised well drained solid ground, availability of minerals, regular supply of fresh water, access to rivers, swamps and estuaries which were the sources of fish and water for agriculture [14]. This explains why most urban environments in the tropical areas are developed in the drainage basins of major streams [15’ 10].

An extra dimension is added to the problem of inadequate research interest by the necessity to specify which water quality constituents are to be monitored to establish the extent of water quality changes influenced by the urban environment. Indeed, the recent raising and specification of effluent standards by FEPA [16] are only now beginning to create awareness for the need to direct research efforts towards the cultural elements that have direct and indirect effect on quality of streams in urbanized catchment systems in Nigeria. This problem justifies the need for us to focus this present investigation on the impact of cultural elements within Enugu urban environment on the water quality of streams in Nyaba catchment area of southeastern Nigeria.

Aim and Objectives

The specific objective is designed to;

- Assess the cultural characteristics of Enugu urban environment capable of affecting the quality of streams in the basin;
- Explain the causal relationships among the predictor variables and the relative strengths of the underlying dimensions of stream water quality in the urban catchment area.

RESEARCH METHODOLOGY

Research Design

Experimental research design was adopted in the study. The present research was experimental because the subjects were investigated in their natural settings.

Area of the Study

This study was conducted in Nyaba catchment area of Enugu state south-east Nigeria. Enugu urban area, the political and administrative headquarters of Enugu State, is located in the Nyaba drainage basin, a humid tropical watershed in the southeastern Nigeria. The study area covers a latitudinal space of $6^0$21' to 6^0 30'N of the equator and longitudinal extent of $7^0$26' to $7^0$37'E of the Greenwich Meridian (see figures 1 and 2). The entire study area covering a spatial entity of about 400sq.km includes the land area under Enugu Town Planning Authority [2].

Population for the Study

The population for the study was infinite.

Sample and Sampling Techniques

The population was infinite hence sampling was considered unnecessary since the entire population was used for the study.

Instrument for Data Collection

The main instrument for data collection was a structured likert scale questionnaire structured in four points. The likert scale options included Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) with scores of 4, 3, 2 and 1 points respectively and were provided to the respondents to place a tick (√) to the response column that best described their level of agreement to each statement in the instrument.

Validation of the Instrument

Face and content validity was established in the research instrument by submitting it to three experts within the field of the study. The experts validated the instrument by making meaningful inputs and corrections which were effected before the final version was reproduced.

Reliability of the Instrument

Cronbach Alpha reliability co-efficient was used to determine the internal consistency of the instrument. The overall reliability coefficient for the instrument was .86. Cronbach Alpha was used because the instrument used was questionnaire and was administered once.

Data Collection

The present investigation in Nyaba drainage basin, data collection was based on the following ten aspects: spatial dimension and configuration of the catchment and sub catchment areas, average slope and altitude of the sub catchment areas, drainage composition of the study area, soil types and distribution in the catchment area, pattern of land use types, sources (industrial, commercial and residential) of waste water production and surface stream pollution in the study area, solid waste and leachate production in Nyaba catchment area, per capita waste water production in the study area, hydraulic, physical (including aesthetic) and chemical characteristics of the stream water in the catchment area, biological characteristics and oxygen requirements of the surface streams.

Method of Data Collection

Effective methods of Characteristics of Nyaba drainage basin, cultural features of Enugu urban environment and physical, qualities of streams in the study area was adopted to source and collect the study data. Also, conventional method of utilizing the topographical water divide to demarcate the boundaries of the sub catchment areas was applied. However, for easy reference and identification of the particular sub catchment area concerned the toponymic system of the sub catchment areas is based on the nomenclature of the pre-existing features in the basin and layouts in the city of Enugu. This means that the nomenclature of the pre-existing layout in Enugu urban area is assigned to the given sub catchment containing greater part of the layout. In order to avoid possible bias, up to twenty five sub catchment areas (each of which has at least a stream of any given order) are sampled and these form the bases for measurement and water sample collection. Gauging stations for stream flow are also set up in the 25 sub catchment areas. Stream flow data is collected from the natural drainage systems in the watershed. The discharge of the rivers is measured by the Velocity–Area technique. This is based on the fact that discharge, Q, is directly proportional to the product of the average stream velocity, V, and the cross sectional area of the river channel, A, at the point of measurement as represented by Jones [5] in the relation:

$$Q = AV \quad (1)$$

Where Q is the stream flow discharge (m^3 /sec); A is the cross –sectional area of the channel (m^2); V is the average stream velocity (m /sec). Each gauging site is carefully selected at such a reach where the river channel is regular without any aquatic vegetation, channel meander or sand deposit to cause obstruction for a length of about 20m to 50m. Floats are improvised to determine the mean velocity of the rivers. The float is made up of a small transparent polythene bag filled with the particular water of the river to be measured. Chukwu [2] has observed that this is necessary in order to make the float acquire the same hydrodynamic properties with the given river water and also travel at the same speed and turbulence with the water to be gauged. The float is dropped at the starting point up stream of the channel stretch to be measured. A stop watch is used in recording the time it takes the float to travel downstream and arrive at the end of the chosen stream reach where the discharge is calculated. The average velocity of the river at the point of measurement is found by:

$$V = \frac{s}{t} \quad (2)$$

Where V is the average stream velocity (m/sec); s is distance of the stretch traveled; t is the time taken by the float to make the travel. Three test runs are made to obtain reliable results in each case. The cross-sectional area of the channel at the measuring site is estimated by the product of the measured channel width (bank full discharge) and the mean stream depth and represented by the equation:

$$A = (\Sigma di/n)\, w \quad (3)$$

Where: A is the cross-sectional area of the stream (m^2); n is the number of points where the stream stage or depth is taken; di is the depth of the stream at points i (i = 1, 2, -------, n); w is the width of the stream channel at the measurement point. Stream flow is of course variable with different types of turbulence and, unlike the design peak run off discharge, the critical dissolved oxygen sag curve can be expected to occur when the turbulent flow is the lowest in the river.

Method of Data Analysis

The research questions were answered using mean scores with standard deviation. One-Way Analysis of Variance (ANOVA) was, however, used to test the null hypotheses at .05 level of significances. For the determination of the degree of agreement of the respondents to each item, for the purpose of answering the research questions, the upper and lower limits of the mean were used thus:

Response	Rating	Boundary limits
Strongly Agree	4	3.50 - 4.00
Agree	3	2.50 – 3.49
Disagree	2	1.50 -2.49
Strongly Disagree	1	1.00 -1.49

Decision Rule

The decision rule for the null hypotheses is that if the calculated F-ratio were equal to or greater than the critical (or table) value, the null hypotheses were rejected otherwise it was not rejected.

ANALYSIS, RESULTS AND DISCUSSIONS

Discussion f Findings

The 182km^2 land of the Enugu municipal area is located in Nyaba drainage basin and according to Chukwu [2, 7], it is characterized by "piece meal" planning approach in which case, the area involved is devoted to a specified urban land use or a named layout. This may be residential, industrial, commercial/ business, open space/green belt/forest reserve or market gardening land use. It should be observed that the percentage of total land areas of Enugu Metropolis devoted to residential, industrial, commercial/business and administrative/institutional land uses have increased in the last decade in the following order: from 62 to 64%, 5 to 6%, 4 to 5% and 5 to 6.5% respectively. On the other hand, the percentage of total land area designed for open spaces/green belt and forestry/ market gardening decreased substantially from 24% to 18.5%. These variations in land use, which took place mainly between 1999 and 2007, during the previous administration, may be accounted for by a number of factors. The state official cemeteries especially those in the sub-catchment areas of Asata River beside Uwani were converted into residential layout, now known as New Site layout. The hitherto famous Enugu Museum occupying large expanse of green land (about 250,000 m^2) is now no more. It has also been converted into residential layout with real concrete "jungle". Furthermore, large areas of forest reserve, over 10ha, especially along water courses in Independence Layout and Trans Ekulu Layout have also fallen prey to urban expansion. The Enugu State Secretariat for Judiciary has now been built in this former forest reserve adjoining Independence Layout. This also contributes to the suspended solid contents of streams through sediment bearing overland flow from construction sites in the basin.

The development and expansion of squatter settlements in the scarp face of the western cuesta especially in Ngenevu area (Alfred Camp) in the sub catchment of Ogbete River at Akwata Police post and Iva Valley Hilly areas. This scarp faces for long resisted human settlement because of its topographical liability. It's beautiful wooded river corridors are fast disappearing making way for squatter settlements which have sprawled beyond the political bounds of the metropolis. Creation of six Local Government Development Centers out of the former Enugu metropolis and building of their administrative headquarters in hitherto green belts area coupled with the present development of more than 10 new layouts have also brought about a decrease in green belt/open spaces in the study area. In fact the destruction of formerly designated (approved) waste dump sites and their conversion to residential quarters have also contributed its own quota to changes in urban land use that pollute the quality of the stream water. This particular action forced many of the Enugu urban inhabitants into disposing of their solid wastes directly into the nearby river channels in Nyaba basin. This adversely affects the quality of the streams in the study area.

Land use Types in the 25 Sub catchment of Nyaba Basin

The sources and causes of stream water pollution in Nyaba catchment area are closely associated with human use of both land and water in Enugu urban environment. The percentage distribution of the various land use types shown in Table 17 are obtained by a comprehensive demarcation of the 25 sub catchment into various land uses with the aid of a network of grids as explained in the study method (section 1.6). Furthermore, the four major categories of land use types were considered. They are residential, commercial/business, industrial and administrative land uses. This exercise is also assisted by the application of aerial photograph the method of which has been explicated earlier in chapter one (1.6). The pervious areas of Nyaba catchment area considered here comprise recreational land uses such as open spaces, play grounds and parks. Others are cemeteries, green belts, forest reserves, gardens and other vegetated surfaces.

A complex and interrelated series of modifications to surface water quality is created by the diversity of land use related human activities in Enugu urban environment impinging on the land phase of the drainage basin hydrological cycle. The major sources and causes of stream water pollution identified during the fieldwork in Nyaba drainage basin are listed in Table 18 under different categories of land use types identified. The table shows that most of the sources and causes of stream water pollution are features of urban environment and can be classified according to their pollution

Domestic Water Utilities in Urban Residential Homes

The normal domestic and municipal activities of Enugu urban inhabitants in their residential houses are among the direct causes and sources of stream water pollution in Nyaba river basin. For instance, in addition to normal domestic sewage, municipal sewage includes wastes from some commercial establishments, hospitals, hotels and institutions. The constituents added to the water during its domestic utility in residential homes include oil, vegetable waste, paper, grit, synthetic detergents, ground garbage, dissolved and suspended organic and inorganic matter, bacteria and various other substances which depend on the commercial and industrial complex which discharge to the artificial sewers in the residential areas. It is these wastes that are delivered to the streams in the sub catchment area receiving the municipal sewage from the residential homes.

Sewage Network

The wastewater produced by the Enugu urban inhabitants and storm runoff are both disposed of through a system of artificial drainage network which conveys the gray water to the natural drainage channels (streams) in Nyaba river catchment area, though without treatment. The artificial drains are provided along the street roads, closes, lanes and avenues in Enugu urban environment. The drains consist mainly of gutters, with open trenches or channels which shape of the cross section may be either trapezoidal or rectangular with concrete lining [7]. Enugu Street guide map shows that there are 280 streets in Enugu urban environment which have artificial drainage channels. These streets have a total of about 700 sewer network with an estimated total length of about 600,000m (600km) in Enugu urban environment. This is a very important aspect of impervious structure in Nyaba catchment area (See Fig. 10). Each urban layout morphology in Enugu portrays a rigid grid system of street network, alongside with storm water and wastewater sewer network combined.

Analysis

Table-1: Percentage distribution of land use types in Enugu urban area of Nyaba Drainage Basin by 1995

S/N	Type of Land Use	Area (Ha)	Percentage of Total Area
1	Residential	11,200	62
2	Industrial	900	5
3	Commercial/Business	700	4
4	Administrative/Institutional	900	5
5	Open Spaces/Green belt/forest reserve/market gardening	4,500	24
	Total	18,200	100

Source: Chukwu, 1995

Table-2: Percentage distribution of Land Use types in Enugu urban area of Nyaba Drainage Basin by 2007

S/N	Type of Land Use	Area (Ha)	Percentage of Total Area
1	Residential	11,648	64.0
2	Industrial	1,092	6.0
3	Commercial/Business	910	5.0
4	Administrative/Institutional	1,183	6.5
5	Open Spaces/Green belt/forest reserve/market gardening	3,367	18.5
	Total	18,200	100

Source: Field Work, 2008

Table-3: Percentage distribution of land use types in each of the 25 subcatchment areas of Nyaba Drainage basin

S/N	Subcatchment Unit	Land use Type (in %) *					
		Res.	Ind.	Comm	Admin	Op & Grn	Total
1	Ekulu R at Abakpa 1st Bus Stop	50	5	12	3	20	100
2	Idaw R. at Achara Layout	82	2	10	1	5	100
3	Nyaba R. at Amagu	26	1	2	1	70	100
4	Nyaba R. at Akwuke	30	2	2	1	65	100
5	Idaw R. at Amechi Road	86	1	5	4	4	100
6	Asata R. at Ilukwe Street	80	3	13	0.5	3.5	100
7	Idaw R. at Timber Shed	52	8	30	3	7	100
8	Ayo R. at Ayo Station	34	2.5	1.5	2	60	100
9	Aria R. at Central Business District (CBD)	20	2	48	20	10	100
10	Ekulu R. at Iva Valley	28.3	0	0.6	0.5	70	100
11	Ekulu R. at Abakaliki Rd, Emene	45	40	5	2	8	100
12	Ekulu R. at Oshimili Street	40	0.4	2.0	0.6	57	100
13	Idaw R. at Idaw R. Layout	51	7.0	10.0	6.0	26	100
14	Asata R. at Independence Layout	41	1	10	20	28	100
15	Ekulu R. at Upper Nike Road	34	11	16	4	35	100
16	Ekulu R. at Maryland	30	4	5	1	50	100
17	Asata R. at New Haven	47	6	7	10	30	100
18	Ogbete R. At Akwata Police Post	30	1.5	36	4	28.5	100
19	Nyaba R. at Enugu-PH Express Rd	10	5.0	10	0.0	75	100
20	Asata R. at Kaduna Street	65	15	17	1.0	2.0	100
21	Asata R. at O'Connor Bridge	75	3.5	18	1.0	2.5	100
22	Ekulu R. at Trans-Ekulu Flyover	30	5	2	0.5	62.5	100
23	Ekulu R. at Ugbodegwu	40	0.3	6	0.7	53	100
24	Idaw R. at Ugwuanji	36	0.4	0.6	0.5	62.5	100
25	Asata R. at CIA (Coal Camp Industrial Area)	63	20	10	1	5	100
	Total	112.3	147.2	288.7	786.3	829.5	2500
	Average	45	6.0	12.0	8.0	33	100

Source: Fieldwork, 2008

Table 2 shows that at present residential land use cover the largest land area of about 11648 ha. This is about 64% of the total land use area in Enugu metropolis. The percentage of total land use under open spaces/green belt/forest reserve and market gardening together covers the second largest area of about 3367ha, representing almost 18.5% of the entire urban land area. The administrative/institutional land use covers about 1183ha representing 6.5%. This is the third largest land use in the metropolis. This is closely followed by industrial land use which covers 1092 ha representing about 6% of land use in Enugu Metropolis. Commercial/Business land use covers the smallest area of about 910ha representing 5% of the entire area (see Table 2).

Table-4: Major Landuse related sources and causes of stream water pollution and their pollution geometry in Nyaba Basin

	Source/Cause	Pollution Geometry *		
		Point	Line	Diffuse
A.	Urban Residential homes			
(i)	Faulty/Leaking cesspit and sewerage system	+	+	+
(ii)	Gray water	+	+	+
(iii)	Street refuse/solid waste	+	O	O
(iv)	Faecal waste	+	O	+
B.	Industrial Landuse			
(i)	Industrial effluent	+	+	+
(ii)	Oily wastes	+	+	+
(iii)	Abandoned coal mines	+	+	+
(iv)	Sand and stone mining in river beds and banks	+	+	+
(v)	Stock piles	+	O	O
(vi)	Scraps	+	O	O
(vii)	Liquid waste	+	+	O
C.	Commercial/Business landuse			
(i)	Discarded/used package containers	+	O	O
(ii)	Liquid waste	+	+	+
(iii)	Abattoir waste	+	O	+
(iv)	Food remnants/wastes	+	O	O
(v)	Fruit peels waste	+	O	O
(vi)	Polythene/Plastic waste	+	O	O

Table-4: Cont

D.	Agricultural Land use			
D1	Market Gardening			
(i)	Irrigation return flow	O	O	+
(ii)	Pesticide	O	O	+
(iii)	Artificial fertilizer	O	O	+
(iv)	Manure & spoil amendment	O	O	+
D2	Animal Husbandry			
(i)	Animal dungs/wastes	+	O	+
(ii)	Liquid waste	+	+	+
(iii)	Animal carcass	+	O	+
E.	Administrative/Institutional			
(i)	Street refuse/litter	+	O	O
(ii)	Solid waste	+	O	O
(iii)	Stock pile	+	O	O
F.	Storm water Runoff			
(i)	Street refuse and ground surface litter	+	O	O
(ii)	Sewage	+	+	+
(iii)	Sediment	+	O	+
(iv)	Liquid waste	+	+	+
(v)	Quick flow	+	+	+

Source: Fieldwork, 2008

Table-5: Major residential wastewater pollutants flowing into Asata River at O'Connor in Enugu Urban Area

S/N	Type of Pollutant	Measurement parameter	Potential environmental impact
1	Biodegradable organic matter	Biochemical Oxygen demand (BOD); Chemical oxygen demand (COD)	Reduces oxygen content of receiving stream water
2	Suspended solid matter	Total suspended solid matter (TSS)	Turbidity; sediment yield
3	Pathogenic bacteria	Faecal coliform bacteria	Health hazard
4	Ammonia	Determine amount of ammonia in wastewater (NH_3^- N test)	Decreases oxygen content; toxic and promotes the growth of algae.
5	Phosphate	Determine phosphate amountin wastewater $PO_4 – P$ test)	Promotes the growth of algae
6	Toxic substances e.g. detergents and tarry substances	Depends on the toxin present	Hazardous to aquatic life and plants. Toxic to man

Source: Fieldwork, 2008

Table-6: Composition of residential wastewater discharge from various types of housing facility from average household in Enugu urban area

S/N	Type of Facility	Pollutant composition (mg/l) in wastewater			
		BOD	COD	Ammonia Nitrogen	Ortho-phosphate
1	Kitchen	597	1204	5.0	11.4
2	Bathing	214	321	0.9	1.0
3	Toilet	300	656	36.5	70.2
4	Laundry	268	608	10.2	115.0
5	Dining	150	250	0.6	0.5
6	Mopping	250	550	5.0	48.0

Source: Field Work, 2008.

SUMMARY OF RESEARCH FINDINGS

The purely natural physical characteristics affecting stream water quality of the 25 subcatchment areas include their spatial size, configuration, average slope and altitude, drainage composition and soil types. Four micro relief regions are discovered in the basin. The first region comprises five sub catchment in the western part of the basin where average altitudes are generally well over 240m asl. And average slope ranges from 10.2^O to 40^O. In the second and third relief regions, mean altitudes and average slope are moderate, ranging from 225 to 239m asl and 5.6^O – 7.80^O respectively. It was discovered that the average slope does not vary in regular fashion with average height in the second and third micro relief regions. The mean altitude in the fourth region is 225m asl or less while average slope varies from 3.8^O to about 6.6^O. The relief features affect mainly the sediment and total solid contents of the stream water. Generally, the mean stream frequency in Nyaba drainage basin is about 1.3 streams per square kilometer but this varies from 3 to about 0.4 streams/sq. km. The particle size of coarse sand ranges from 0.5 to 1.0mm and it has the highest particle size distribution among the various classes of soil in the study area. The least is observed for the clay soil in Idaw R. at Idaw R. Layout (0.002 – 0.004mm). Both the stream frequency and particle size of soil affect the quantity and quality of solids and pollutants.

CONCLUSION & RECOMMENDATIONS

As a nuisance, sewage in the urbanized catchment area of the watershed constitutes an eye-sore with its pungent irritating odour like rotten egg. It is important to emphasize that the protection of natural recreational facilities, such as swimming pools, the prevention of surface water pollution, the maintenance and restoration of ambient conditions and ecological integrity of the urban streams and the exercise of common decency offer tangible and intrinsic justifications for the treatment of sewage in the urbanized part of Nyaba catchment area and be properly adhered to. Municipal sewage treatment work is therefore strongly recommended to prevent water pollution caused by sewage constituents. Since some of the streams such as Ogbete, Asata, Ekulu and Nyaba rivers serve as both drainage channels and sources of domestic water supply to the local inhabitants, the treatment of sewage is necessary to minimize the pollutant load of the surface stream on the treatment plant.

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