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An Investigation into the Biological Characteristics and Oxygen Status of Stream Water in Nyaba Catchment Area of South Eastern Nigeria

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Original Research Article

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Abstract: This investigation is conducted in Nyaba drainage basin, a 400km2 instrumented humid tropical urban watershed in Southeastern Nigeria to investigate into the biological characteristics and oxygen status of stream water in Nyaba catchment area. Samples of stream water and solid waste leachate were collected from 25 subs 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 velocity 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 study therefore recommends a redirection of present efforts from water treatments focusing on physico-chemical quality to microbiological quality surveillance with a sustainable solid waste disposal practice in the Enugu urban environment to restore and protect the ambient stream water quality in Nyaba catchment area.

Keywords: Biological Characteristics, Oxygen Status, Stream Water, Catchment Area.

INTRODUCTION

The distribution and abundance of stream macro invertebrates are influenced by a variety of physical and biological factors. Abiotic factors, in particular those related to disturbance [1, 2] and habitat heterogeneity [3-5], clearly determine the composition of invertebrate communities. However, habitat factors influencing community structure differ among systems and with the spatial scale of the study.

Ecologists have long recognized that habitat factors represent filters for biological traits, and patterns in these traits are related to spatial habitat variability a well as to disturbance.

These ideas were related to the 'habitat templet concept' of South wood [6]. It postulates that spatial-temporal habitat variations provide a 'templet' against which differences in fundamental life history and other species traits result in differential survival and reproduction. Townsend & Hildrew [1] thus developed a 'river habitat templet' by predicting trends of traits across spatial-temporal variability gradients. Temporal variability was understood as the frequency of disturbances, whereas spatial variability referred to the abundance of refugia buffering the effect of disturbances [1, 4]. In recent tests of the habitat templet concept in streams, trends in species traits have often proved significant [4, 1, 7, 8].

Hydrological variation is commonly viewed as an important element of the habitat templet, suggesting differences in ecosystem structure and function in streams [2]. Mediterranean regions are characterized by high hydrological variability [9], even more accentuated in Mediterranean semi-arid zones. Thus, organisms that frequently experience abiotic disturbances (floods and droughts) may respond over evolutionary time by developing morphological, physiological and/or life-history traits that minimize the impact of disturbances. A study area with a hydrological disturbance gradient determined by climate would then be good for revealing contrasts among biological traits characterizing macro invertebrate communities.

In addition to these climatic and hydrological features, a major feature is that some of the tributaries in the southeastern part of the basin flow across salt rich rocks and therefore their salinity is sometimes very high. These saline streams have marked differences in taxonomic composition compared with their freshwater counterparts in the same region [10, 11]. In recent years, increasing population and increased use of surface water and groundwater for crop irrigation have created conflicts in water resources management.

Continuous drought and increased water withdrawal has brought record low flow to streams in the LFRB [12]. Low-flow events often lead to increased temperatures in summer due to high heat energy input and low heat buffer capability. High temperatures may also exacerbate oxygen problems in low gradient streams [13-15]. Together, these can decrease the availability of aquatic habitat and thus decrease fish diversity and populations [16, 17].Increased water demand and use has been identified as one of the primary problems threatening stream fishes and other aquatic biota in the Southeastern U.S [18]. To protect stream flows in these tributaries of the LFRB, the state has established the Flint River Drought Protection Act (FRDPA), initiated in March 2001, to limit farmland irrigation from surface water during drought seasons. However, the efficacy of the FRDPA depends on whether natural resource managers and planners are informed as to the nature and extent of potential impacts. Also, there are proposals to construct dams to regulate the water distribution in different seasons. The effect that the proposed dams would have on downstream aquatic habitat, especially on stream water temperatures and dissolved oxygen, needs to be predicted and evaluated beforehand. Therefore, there is a need for natural resource managers and planners to have a clear understanding of stream water quantity, quality, and their interactions.

Statement of the Research Problem

Unfortunately many people in African countries including Nigeria until recently regard the concern for changing quality of urban streams as a less important issue which may distract attention from the more urgent and serious problem of achieving a fast rate of economic growth. This attitude stems in part from the belief that environmental degradation is an inevitable price of development [19-22]. However, within the past few years, there has been a perceptible shift of attitude as the realization that measures to solve or ameliorate ecological degradation deserve to be accorded a high priority [23-25]. In spite of this new awareness, Africa still lags behind especially in the current debate on the global environmental change. Indeed, research interest on water quality changes in urban environment has been relatively one-sided dominated by the more developed countries and with Africa particularly remaining mainly on the sideline [19]. However, some African countries have taken some interim measures by establishing guidelines and standards to protect the quality of their urban water resources. The Federal Government of Nigeria for instance through the promulgation of Act 58 of December 1988 established the Federal Environmental Protection Agency (FEPA). Sections 16 and 17 of the Act mandated the Agency to protect, restore and preserve the quality of streams and ecosystems of Nigerian environment [26]. Unfortunately very little attention currently is being given to scientific research in Nigeria to assist FEPA and environmental authorities in achieving these laudable objectives. Yet, it is globally accepted that where there are threats of serious water quality deterioration and other irreversible environmental damages, lack of scientific research interest should not be used as a reason for postponing measures to mitigate water quality deterioration. For instance, Ezekwesili [24] and Nnodu [27] have observed that with increasing population pressure of Enugu urban area on land and water resources of Nyaba catchment area, the pollution rates of the urban rivers have attracted much attention. Most recent work carried out by Ezemonye [25] has also pointed out that the domestic and industrial activities in Enugu urban environment create problems of waste disposal that have adverse impacts on the quality of both surface and groundwater resources of Nyaba urban basin.

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 [19] are only now beginning to create awareness for the need to direct research efforts towards the ecological integrity and quality of streams in urbanized catchment systems in Nigeria. Ofomata [11], Eze [24], Adibe, Chukwu and Ewurum [21] have therefore strongly observed that in spite of increase in stream water pollution problems in Nigerian cities, very little research work has been done to study and assess the magnitude of problems involved. This problem justifies the need for us to focus this present investigation on the effects of Enugu Urban environment on the water quality of streams in Nyaba catchment area of southeastern Nigeria.

Aim and Objectives

The broad aim of this work is to ascertain whether there are impacts in water quality of streams in Nyaba watershed as a result of human activities in Enugu urban environment. To achieve this broad aim, the specific objective is designed to:

- Examine the biological characteristics and oxygen status of stream water in Nyaba catchment area.

RESEARCH METHODOLOGY

Research Design

The research design for the study was the survey and experimental research design. The present research was a survey because the subjects were investigated in their natural settings. Secondly, the survey research involved questionnaire as its main instrument for data collection and cuts across various segments of Enugu town.

The Study Area

The study was conducted in Nyaba catchment area of Enugu state south-east Nigeria. The researcher's choice of the study area has majority based on his being conversant with the South east geographical zone of 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. The entire study area covering a spatial entity of about 400sq.km includes the land area under Enugu Town Planning Authority [28].

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 questionnaire entitled. The instrument has response options of 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

The validators did not discard questionnaire items but restructured several of them to enhance understanding and clarity. Their comments were utilized in producing the final instrument, some of the comments includes: number all the questionnaire items serially from sections to the end, reduce the wordings by introducing opening statements, make each questionnaire item to be specific, that is to address a particular issues and as much as possible reduce verbosity of the items.

Reliability of the Instrument

Cronbach Alpha reliability estimate was used to determine the internal consistency of the instrument. The results generated were used for reliability analysis. The data were calculated using Cronbach Alpha reliability co-efficient formula and it yielded .95, .89, .94 and .93 for the four respective clusters. The overall reliability coefficient index for the instrument is .86. Cronbach Alpha was used because the instrument used was questionnaire and was administered once.

Data Collection

This subsection deals with what the researcher observed in the study area, as empirically supported investigations are usually based on partial (sample) information. Nachmias and Nachmias [29] have noted that this is the case because it is often impossible, impracticable and extremely expensive to collect data from all the potential unit aspects of the population encompassed in the research problem. Nevertheless, precise inferences on all the units based on relatively small number of units are drawn because the sample characteristics accurately represent the relevant attributes of the whole set. Therefore the major purpose of defining the aspects of our data is to provide accurate estimates of unknown parameters from sample characteristics which are easily analyzed. To realize this in our 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.
- Usually, sampling units have numerous aspects and attributes, one or more of which are relevant to the research problem [37]. Hence having decided on the relevant aspects of data to observe, we proceed to the data collection stage.

Method of Data Collection

In order to minimize the risk of erroneous presentation of our major aspects of data enumerated above, we adopted effective methods to source and collect our data on

- Characteristics of Nyaba drainage basin
- Cultural features of Enugu urban environment.
- Physical, qualities of streams in the study area.

In this work, we apply the conventional method of utilizing the topographical water divide to demarcate the boundaries of the sub catchment areas. 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. The multi–stage sampling is chosen here because it is intended to overcome the problem of simple probability sampling especially the chance of under or over representing certain relevant attributes of the urban and sub catchment areas [23, 30]. 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 [2] 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 [28] 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 DISCUSSION OF FINDINGS

Biological Characteristics and Oxygen Status of Streams in Nyaba Catchment Area

The researcher examines the biological, particularly the microbial characteristics and oxygen requirements of the stream water in the 25 subscatchment areas of Nyaba basin. The term “microbial characteristics” as used in this work refers to the extent of occurrence of some species of microscopic living organisms, particularly disease causing agents (commonly known by workers as microbes) involved in routine water quality analysis [31, 32, 33, 5]. Oxygen is required in water to maintain most forms of aquatic life and to allow the decomposition of organic matter including organic effluents and thus to ensure the continued existence of urban streams as usable resources in their natural catchment area [12]. The most significant impact on the oxygen content of stream water in an urban catchment area is caused by biodegradation of the wastes especially organic waste matter. It is this effect which is employed in the determination of the oxygen status of an effluent receiving stream in our urban basin under investigation.

Microbes from Sewage Receiving Streams in Enugu Urban Environment

Pathogens which are discovered in sewage receiving streams of Enugu urban environment are shown in Table 1. They include different species of worms, protozoans, bacteria and hepatitis A virus. The microbial analysis of the 25 water samples show that these pathogens are found mainly in seven highly urbanized subcatchment areas of the study area. These subcatchments are Asata River at Kaduna Street, O'Connor Street, Ilukwe St. and CIA, Idaw River at Timber shed Ogbete River at Akwata Police Post and Nyaba River at Akwuke. This is probably because microbes which are pathogenic to

Table-1: Microbes found in sewage and faecal contaminated surface streams of Enugu urban environment

S/N	Species and strains of Microbial vector	Associated disease *	Place mainly found
1.	Worms		
(i)	*Necator Americanus*	*Ancylostomiasis* (hookworm)	Asata R. at Kaduna St. CIA, and O'Connor, Nyaba R. at Akwuke, Ogbete R. at Akwata Police Post
(ii)	*Ascaris Lumbricoides*	*Ascariasis* (round worm)	
(iii)	*Taenia solium*	*Taeniasis/ cysticerocosis* (Pork tapeworm)	
2.	Protozoans		
(i)	*Entamoeba histolytica*	*Amoebiasis* (Amoebaic dysentery)	Ogbete R. at Akwata Police Post, Asata R. at Kaduna St. and Ilukwe St.
(ii)	*Giardia lamblia*	*Giardiasis*	
3.	Viruses		
(i)	*Hepatitis A virus*	Infectious *hepatitis*	Asata R. at CIA &O'Connor St.
4.	Bacteria		
(i)	*Salmonella typhi*	*Typhoid fever*	Asata R. at Kaduna St, Ilukwe St., Idaw R. at Timber shed
(ii)	*Salmonella paratyphi*	*Paratyphoid fever*	Asata River at Kaduna, St. Ilukwe St. and O'Connor
(iii)	*Salmonella Newport*	*Gastroenteritis*	
(iv)	*Salmonella typhimurium*	*Gastroenteritis*	
(v)	*Vibrio cholera*	*Cholera*	
(vi)	*Enterobacter aerogenes*	*Septicemia*, urinary tract infection	
(vii)	*Shigella sonnel*	Bacillary dysentery	Asata R. at Kaduna, Ogbete R. at Akwata
(viii)	*Shigella Flexner*	Bacillary dysentery	Idaw R. at Timber shed, Asata R. at Ilukwe and O'Connor St.
(ix)	*Clostridium tetani*	Tetanus (lock jaw)	Asata R. at Kaduna St.
(x)	*Clostridium botulinum*	*Botulism* (food poisoning)	Idaw R. at Timber Shed
(xi)	*Clostridium perfringes*	Gastroenteritis, diarrhea	"
(xii)	*Staphylococcus aureus*	Food poisoning, mastitis, abscesses boils, carbuncles, infantile impetigo	"
(xiii)	*Pseudomonas aeruginosa*	Ear and urinary tract infections, ulcers, wound and born infection, diarrhea	Asata R. at C.I.C. Rd and Kaduna St.
(xiv)	*Streptococcus faecalis*	Causes throat infection and also indicates human fecal contamination of water	Ogbete R. at Akwata, Asata R. at Kaduna St.

Sources: Fieldwork, 2008.

Coliform Group of Bacteria in Stream Water

Coliforms are aerobic but facultative anaerobic gram-negative, non-spore forming, rod shaped and cytochrome oxidase negative [33]. An average urban man may discharge 1.5 x 10^{11} total coliforms per day or 3.2 x10^{10}*faecal coliforms* per day [5]. Therefore even if a sewage treatment plant is to be installed in Enugu urban area, and it achieves about 99.9% reduction in faecal coliform (an unlikely high attainable efficiency level) there are still about 3.2 x 10^{7} number of coliform bacteria remaining per head per day in the city. The bacteriological quality of our stream water samples is analysed in the laboratory.

After preparing the 10 sterilized culture bottles (as explained in Section 1.6) 10ml of water sample are introduced into the first group of five sterilized culture bottles containing the media and the indicator solution. A sterilized plastic is used in adding the sample to the bottles. The bottles are labeled and the amount of water sample in each bottle is also recorded. 1ml of water sample is introduced into each bottle in the second group of five bottles. The bottles are incubated for 2 days (48hrs) at 35^{0}C temperature.

After 48 hours, the bottles were observed for colour change thus
* Positive Test – Bottles changed from purple to yellow;
* Negative Test –No change in colour.

The number of bottles with positive results for each of the concentrations was recorded. The Most Probable Number (MPN) index of coliform organisms was utilized in the final analysis to estimate the number of coliforms per 100ml of the water sample. The coliform group of bacteria is of special importance in surface water study of this nature. As noted by Bratvold *et al.* [34], Clark and Robinson [5], coliform bacteria are generally non-pathogenic, but since many of them are of intestinal origin, their presence indicates the presence of pathogenic bacteria in stream water of a catchment system. *Escherichia coli* is an important diagnostic coliform organism and is used as an indication of the probable occurrence of domestic sewage since it is always found in human intestine. However, it also lives in other mammals as well.

Table-2: Most Probable Number Indices for Coliform Organisms in Water Sample

	Number of positive tubes		MPN /100 ml
S/NO	10ml	1ml	Of water
1.	0	1	2.0
2.	1	0	2.2
3.	1	1	4.4
4.	2	0	5.0
5.	2	1	7.6
6.	3	0	8.9
7.	3	1	12.0
8.	4	0	15.0
9.	4	1	21.0
10	5	0	39.0
11.	5	1	Indeterminate

Source: Schulz and Okun, 1992; p278

Table-3: Analysis of microbiological quality of stream water in Nyaba Catchment Area

S/N	Subcatchment Unit	Streptococcus faecal	Coliform group/ 100ml	E-coli/ 100ml	Total plate-count per ml
1	Ekulu R at Abakpa 1st Bus Stop	+	189.0	80.0	140
2	Idaw R. at Achara Layout	++	102.0	49.0	116
3	Nyaba R. at Amagu	O	10.0	2.0	108
4	Nyaba R. at Akwuke	+	115.0	5.0	125
5	Idaw R. at Amechi Road	++	86.0	11.0	136
6	Asata R. at Ilukwe Street	+++	200.0	21.0	192
7	Idaw R. at Timber Shed	+++	164.0	65.0	184
8	Ayo R. at Ayo Station	+	10.0	5.0	110
9	Aria R. at Central Business District (CBD)	++	50.0	4.0	130
10	Ekulu R. at Iva Valley	O	3.0	1.0	109
11	Ekulu R. at Abakaliki Rd, Emene	+	20.0	8.0	101
12	Ekulu R. at Oshimili Street	O	15.0	3.0	115
13	Idaw R. at Idaw R. Layout	+	105.0	26.0	155
14	Asata R. at Independence Layout	+	12.0	4.0	145
15	Ekulu R. at Upper Nike Road	++	135.0	44.0	153
16	Ekulu R. at Maryland	+	12.0	4.0	107
17	Asata R. at New Haven	+	16.0	5.0	130
18	Ogbete R. At Akwata Police Post	+++	150.0	70.0	185
19	Nyaba R. at Enugu-PH Express Rd	O	9.0	2.0	115
20	Asata R. at Kaduna Street	+++	230	89.0	208.0
21	Asata R. at O'Connor Bridge	+++	206.0	88.0	195
22	Ekulu R. at Trans-Ekulu Flyover	O	10.0	2.0	108
23	Ekulu R. at Ugbodegwu	+	108.0	8.0	135
24	Idaw R. at Ugwuanji	+	21.0	7.0	113
25	Asata R. at CIA (Coal Camp Industrial Area)	++	111.0	48.0	123
	WHO MPL	0/100 ml	3/100ml	0/100ml	100/ml

Source: Fieldwork, 2008.

Total Plate Count

The result in Table 3 shows that the total bacterial plate count per ml of the water sample varies from 101 per ml in the subcatchments area of Ekulu River at Abakaliki Road to a maximum of 208 per ml in Asata River at Kaduna Street. This gives a range of about 107 per ml with an average concentration of about 155 per ml. This simply shows that the major problem created by the Enugu urban environment on the streams of Nyaba catchment area is microbiological pollution and not necessary chemical and physical pollution. This is because each of the 25 subcatchment areas has a standard total plate count number of bacteria being greater than the WHO maximum permissible limit of 100 bacteria per ml. (See Table 3).

The worst microbiologically polluted stream water is Asata River at Kaduna Street which has 208 per ml, followed by Asata River at O'Connor St. with 195 plate count per ml. The third worst affected is still Asata River at Ilukwe St. (192 per ml) followed closely by Ogbete River at Akwata Police Post and Idaw River at Timber shed with 185 per ml and 184 per ml respectively.

This is not surprising because these subcatchment areas receive large quantities of grey water from the Enugu urban environment which also in turn explains the occurrence of the coliform group and *E.coli* in the stream water of Nyaba drainage basin.

Viruses in Stream Water

Viruses are *obligate* parasites, which in their inactive form are very resistant to disinfection agents and may survive a long time in surface water resource [34]. They are discharged in human faeces and urine but only the one found in large numbers and identified in the laboratory is of concern to us. The human virus of concern in the study area is infectious hepatitis virus (See Table 36). It is also the only one with the epidemiological evidence of being transmitted through contaminated stream water. Unfortunately as pointed out by workers like Meyers [33], Brussard *et al.* [34] no tissue cell culture technique has yet been invented to grow and isolate this virus outside a host but Clark and Robinson [5] have explained that laboratory and immunological techniques are available for its detection in stream water samples. Viruses can only grow in living cells; but the main threat in Enugu urban environment comes from large population of the city. Human enteric viruses are produced by infected urban inhabitants and excreted faecally, consequently contaminating sewage effluents which are discharged into the streams of the study area. Abstraction and treatment of the stream water for domestic purposes may not remove all the viruses.

Protozoans and Helminthes in Surface Water

Protozoans are one celled microscopic organism frequently occurring in a surface water body and may be a vector of diseases to man [32]. Helminthes are parasitic worms most often living in human intestines and which can also cause ill health to humans. These microbial pathogens are also detected in the sewage receiving streams in Enugu urban environment.

Protozoans in Stream Water

Table 1 show that two major species of protozoa are found in streams of the study area. They are Entamoebahistolytica and Giardialamblia and they are the major causes of Amoebiasis (Amoebaic dysentery) and Giardiasis. These two pathogens are discovered in three subcatchment areas of Ogbete River at Akwata, Asata River at Kaduna St. and Ilukwe St. *Entamoebahistolytica* is spread mainly by contaminated stream water and by sludge used as fertilizer in market gardens along the banks of the streams while Giardia Lamblia is found mainly in polluted stream water within Enugu urban environment and is resistant to ozone and even chlorine treatment. It is an indication of faecal contamination of the stream water in those three subcatchment areas of Nyaba basin. The faeces usually contain the cysts which are also spread by using faeces as fertilizer on fruit and vegetable gardens along the banks of the streams. *Giardialamblia*, an intestinal protozoan affects the mucosa of the duodenum. The trophozoites when present in great numbers interfere with food nutrient absorption in human system. Hence malabsorption symptoms and diarrhea may occur especially in children within the endemic urban environment.

Helminthes in Stream Water

Helminthes are parasitic worms, which cause ill health to human. Laboratory test results of the microbes found in streams of the study area show that the four major types of helminthes eggs present in the streams include *Necator Americanus* which causes Ancylostomiasis (or hook worn), *Ascaris lumbricoides* which causes ascariasis (round worm), *Taenia saginata*, the major cause of cow tape worm (Taeniasis) and Taeniasolium that causes cysticerocosis (pork tape worm) in man.

NecatorAmericanus and Ascarislumbricoides are discovered in Asata River at Kaduna St., CIA, and O'Connor while Taenia (saginata and solium) is found in the two subcatchment areas of Ogbete River at Akwata Police Post and Nyaba River at Akwuke (See table 1). In these subcatchment systems, large number of cattle is usually taken down the stream to drink water. In fact the Gariki at Enugu is found in the subcatchment area of Nyaba River at Akwuke Awkunanaw. It is where large number of cattle are temporarily kept awaiting slaughter or sale. The eggs of the helminthes are discharged in faeces. The larvae in the soil or stream water penetrate to the human body through the feet or mouth.

Oxygen Status of Stream Water in Nyaba Catchment Area

The most significant impact on the oxygen resources of stream water in Nyaba basin is caused by biodegradation of the organic matter. It is this effect that the researcher employed in the examination of the oxygen demand in sewage receiving streams of Nyaba catchment area. The measurement of oxygen demand of effluent receiving stream requires the determination of the dissolved oxygen content.

Dissolved Oxygen (DO) Contents of the Streams

The most important dissolved gas present in the stream is oxygen. Nitrogen is present in most stream water but it is of little significance with respect to general water quality of the stream [35, 19, 36, 33]. Oxygen dissolved in the surface streams of Nyaba catchment area comes from two major sources, namely (i) the troposphere (atmosphere) (ii) the photosynthetic processes of green plants.

Biochemical Oxygen Demand (BOD)

The rate at which oxygen is consumed in stream water is perhaps, more important than DO. Biochemical oxygen demand (BOD) is not a specific stream water pollutant but rather a measure of the amount of oxygen required by bacteria and other micro-organisms engaged in stabilizing decomposable organic matter. The BOD test has been standardized by requiring the test to be run in the dark at 20^{O}C for five days. The 5-day 20^{O}C BOD (BOD_5) is the oxygen amount consumed by micro-organisms in the water.

Results of laboratory analysis of Oxygen status of surface stream water in Nyaba Catchment Area (mg/l)

S/N	Subcatchment Unit	DO	BOD	COD	PV Test
1	Ekulu R at Abakpa 1st Bus Stop	8.0	3.5	5.5	1.4
2	Idaw R. at Achara Layout	7.8	21.0	340.0	83.5
3	Nyaba R. at Amagu	8.3	1.5	3.2	0.5
4	Nyaba R. at Akwuke	7.3	20	42	8.0
5	Idaw R. at Amechi Road	7.35	6.5	10.5	3.0
6	Asata R. at Ilukwe Street	8.4	200	350	80.5
7	Idaw R. at Timber Shed	7.4	230	400	92.0
8	Ayo R. at Ayo Station	7.7	4.0	7.0	1.6
9	Aria R. at Central Business District (CBD)	7.3	1000	150	40.0
10	Ekulu R. at Iva Valley	7.8	2.4	3.8	0.96
11	Ekulu R. at Abakaliki Rd, Emene	7.9	40	70	16.0
12	Ekulu R. at Oshimili Street	7.85	2.1	3.5	0.85
13	Idaw R. at Idaw R. Layout	7.50	180	280	72.0
14	Asata R. at Independence Layout	8.10	7.0	11.0	3.0
15	Ekulu R. at Upper Nike Road	7.0	210.0	350	84.0
16	Ekulu R. at Maryland	7.85	10.0	15.0	4.0
17	Asata R. at New Haven	7.82	25	41.0	10.0
18	Ogbete R. At Akwata Police Post	7.65	200	320	80.60
19	Nyaba R. at Enugu-PH Express Rd	7.81	2.0	3.5	0.85
20	Asata R. at Kaduna Street	7.5	260	420	104.0
21	Asata R. at O'Connor Bridge	7.9	240	400.0	96.0
22	Ekulu R. at Trans-Ekulu Flyover	7.8	2.5	4.0	0.9
23	Ekulu R. at Ugbodegwu	8.0	50	80.0	20.0
24	Idaw R. at Ugwuanji	8.2	15.0	24.0	6.0
25	Asata R. at CIA (Coal Camp Industrial Area)	7.95	10,000	14,000	4000

Source: Fieldwork, 2008.

SUMMARY OF RESEARCH FINDINGS

The purely natural physical characteristics affecting stream water quality of the 25 subcatchments 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 subcatchment 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

Municipal sewage treatment work is therefore strongly recommended to prevent water pollution caused by sewage contaminants. 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. 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. This study recommends an environmental education model which is focused towards a wide-scale participation in environmental stewardship education. This is a departure from the old traditional model that has largely been aimed at awareness creation only for surface water pollution impacts. In our proposed model, the aim will be to show how participatory approaches to environmental education can inculcate the necessary skills that will enable us take active participation in environmental stewardship and actions to protect our surface water resources and control water pollution in the city.

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