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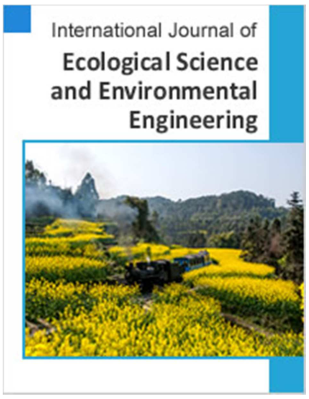

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Assessment of Impact of Industrialisation on Some Physicochemical Parameters of Fresh Waters Around 9th Mile Corner, Enugu State, Nigeria

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Abstract
Some physico-chemical parameters/pollution indicators on ground and surface water around industrialised part of 9th mile corner, Enugu urban and Ajalli stream all in Enugu State, Nigeria, were ascertained using standard methods. The pH ranged from 6.5 - 8.5 at the water temperature between 26°C to 30°C. Turbidity of 5.00 NTU and slightly above were observed, with the total dissolved solids of 12.94, 31.96 and 867.93mg/l for 9th mile, Enugu urban and Ajalli stream respectively, while the total suspended solids were 2.70, 5.32 and 59.32mg/l respectively. The biological Oxygen demand and dissolved oxygen ranged from 1.33-10.00mg/l and 1.43mg/l - 5.85mg/l respectively, with chemical Oxygen demand value of 4.47, 3.7, and 24.95mg/l, and chloride ion concentration of 7.67 and 7.32, and 154.32mg/l for the 9th mile, Enugu urban and Ajalli stream respectively. The total hardness and electrical conductivity ranged from 17.42 to 112.57mg/l and 53.32-985.67µcm/s respectively. Therefore, despite the rapid industrial growth, the ground water in 9th mile corner of Enugu State, Nigeria, can be used for both domestic and industrial purposes with little or no treatment. It provides business opportunities and is suitably recommendable for industries specialized in the manufacture of beverage drinks and/or related products.

1. Introduction

9th mile is located in Udi Local Government Area of Enugu State (Latitude 6° 30°N, Longitude 7° 30°E and 223 m above sea level). The 2006 Nigerian population census put its population at 25,000 people. It has developed into a sprawling industrial settlement hosting important industries like the Nigerian Brewery Plc Plant, AMA Brewery plant, Seven-Up Bottling Company production Plant, Nigeria Bottling (NB) Company Plant, East Chase Aluminum finishing and coupling plant, Nondon paper mill, and Rapha group of companies, as well as over twenty table water production companies, and other associated concerns. It is today the industrial hob of Enugu state with bustling environmental and social activities and a revenue spinner for Udi Local Government Council, Enugu State and Federal Governments of Nigeria.

Industrialisation is inadvertently accompanied by seeds of environmental damage, abetted by both needs and greed of man [1]. Activities such as manufacturing, processing, transportation and construction not only deplete the stock of natural resources but also add stress to the environmental system by accumulating stock of wastes [2]. The productivity of the industries however, depends on the supply and quality of natural and environmental resources. Many countries, particularly Nigeria, embark on various industrialisation plans, strategies and polices in order to provide employment opportunities, raise the general standard of living, boost income, pay off both national and international debts, and promote export and technical skills [3]. The wonderful gains of industrialisation notwithstanding, a spontaneous conflict in the minds of environmentalist take place with the juxtaposition of the words "industry" and "environment"[2]. Contamination of drinking water supplied from industrial waste is as a result of various types of industrial processes and disposal practices. Industries that use large amounts of water for processing have the potential to pollute waterways through the discharge of their waste into streams and rivers, or by run-off and seepage of stored wastes into nearby water sources.

Over 70% of the Earth's surface is covered by water, this alone makes water a very important issue. However, the Earth's water resources and potable water supply is in danger of becoming contaminated [4]. When water becomes contaminated, it is considered polluted [3]. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Natural water contains different types of impurities introduced into aquatic system by mechanization and industralisation which comes from different ways such as; automobiles, combustion engines, toxic industrial effluents, waste water from various industries, weathering of rocks, leaching of soils, agricultural wastes, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, abattoirs, warehouses, processing firms that make use of metal based materials [5, 6]. High level of pollutants mainly organic matter in river water causes an increase in biological oxygen demand, chemical oxygen demand, total dissolved solids, total suspended solids and fecal coli form. The Earth never increases the amount of water it contains, nor does it ever lose any of its water. The Earth's water is recycled in three ways: evaporation, condensation, and precipitation. When the sun heats up the Earth's oceans, rivers, and lakes the water is turned into water vapor or steam (evaporation). When the water vapor rises into the atmosphere it collects in the forms of clouds (condensation). When clouds get too saturated and heavy with water vapor, they release it in the form of precipitation (rain, snow, sleet, etc.). If a pollutant is added into any step of the water cycle, the whole cycle is affected. Groundwater contamination from industralisation occurs when manmade products such as gasoline, oil, fertilisers, pesticides and other chemicals get into groundwater and cause it to be unsafe and unfit for human use [7]. In most developing countries where dangerous and highly toxic industrial and domestic wastes are disposed by dumping them into rivers and streams with total disregard for aquatic lives and rural dwellers, water becomes an important medium for the transmission of enteric diseases in most communities. Poisonous chemicals are known to percolate the layers of the earth and terminate in ground waters thereby constituting public health hazards [8]. Most often our waterways are being polluted by municipal, agricultural and industrial wastes, including many toxic synthetic chemicals which cannot be broken down at all by natural processes. Septic systems, hazardous waste sites and landfills are major targets of pollution because rainfall and groundwater leach these highly contaminated substances into rivers, stream and waterways (surface water) which are inadvertently used by people in that area. [9]. Due to population and industrial growth in land, water (river, lakes boreholes etc) become often the recipient of organic matter in amounts exceeding their natural purification capacity, while in the past, natural purification and dilution were usually sufficient [10]. Heavy metals are natural components of the environment, being present in rocks, soil, plants and animals. They occur in different forms: as minerals in rock, sand and soil; bound in organic or inorganic molecules or attached to particles in the air. In today's industrial society, there is no escaping exposure to toxic chemicals and metals. This is so because somehow, our society is dependent upon metallurgy for proper functioning [11]. It is therefore not surprising that human exposure to heavy metals has risen dramatically in the last 50 years as a result of an exponential increase in the use of heavy metals and/or their compounds in industrial and agricultural processes. Environmental contamination and exposure to heavy metals is a serious growing problem throughout the world, as both natural sources and anthropogenic processes emit heavy metals into various environmental media. Chemical investigation of the water quality of some borehole water source in some industralised part of the country [12, 13, 14] reveals that water that was once an abundant natural resource is rapidly becoming scarce in quantity (high demand) and the quality is deteriorating in many places owing to industrial activities. In year 2003, Nigerian National Agency for Food and Drug Administration Control (NAFDAC) at Oshodi in Lagos State analysed some borehole water samples for registration purpose, and the majority of the samples analysed showed high microbial load [15]. Studies carried out on selected water sources in industralised part of the city including underground water in Calabar indicated that the physicochemical parameters, biological oxygen demand (BOD), silica and pH were positively correlated with indicator bacteria with counts reaching a maximum of 520 faecal coliforms per 100ml [8]. The quality of the water samples therefore did not conform to the approved WHO standard for drinking water. In a survey on water quality at the oil depots of the Nigeria National Petroleum Corporation (NNPC) Ejigbo, Lagos State and Apata in Ibadan, the hydro chemical analysis results revealed that the ground water in the areas (Lagos and Ibadan Depots) were of $Ca(HCO_3)_2$ type which was influenced by the industrial activities in the area and geologic materials. The water was acidic to neutral in character, very hard and fresh. Water from the wells did not meet the WHO drinking water standard and were declared unfit for human consumption due to total hydrocarbon and bacteriological pollution. In the study of the effects of industralisation on underground water in Bada city Kano state, the result revealed that exhaust fumes from machines, vehicles, smoke from dumpsites constitute a large portion of the pollutant in the area. Total hydrocarbon, household waste disposal and seepage from septic tanks were the major sources and causes of ground water pollution [16]. The incidents of water borne disease and epidemics nationwide arising from drinking water of doubtful quality have become of great concern. The primary purpose of the guideline for drinking water quality is the protection of public health. As described by Horsefall and Spiff [17], water quality standard is a measure, principle or rule established by authority set to protect the water resource for uses such as drinking water supply, recreational uses and aesthetics, agriculture (irrigation and livestock watering), protection of aquatic life and industrial water supplies.

This study is aimed at assessing the influence of industralisation on some physico-chemical parameters/pollution indicators on ground and surface water around the highly industrialised part of 9th mile corner in Udi Local Government Area of Enugu State, Nigeria.

2. Methodology

2.1. Preliminaries

2.1.1. Selection of Sampling Points

The criteria for selecting sampling points were based on the population density, areas of industrial or anthropogenic activities such as abattoirs, wood processing industries, chemical and biological laboratories, agro allied industries, marketing activities, mechanic village, car parks and the river catchment areas.

2.1.2. Sample Collection and Preparation

Comparative water sampling was carried out on the water samples from the boreholes within the study area, Enugu urban which is about 15km away from the study area and Ajalli stream a few mile from the study area from July 2014 to December 2014. Water samples were collected manually with sterilized plastic containers from either the tap or directly from the boreholes through the hose on boreholes. The containers were carefully labeled and transported immediately in a container for physicochemical and heavy metal analysis, while some parameters were determined at point of sampling. Physicochemical parameters analyzed were; pH, temperature, turbidity, total suspended solids, dissolved solids, chloride ion concentration, electrical conductivity, total hardness, chemical oxygen demand, dissolved oxygen, and biological oxygen demand.

2.2. Physicochemical Analysis

2.2.1. pH

A digital pH meter metrohm 632 was standardized with buffer solutions of pH 4, 7 and 9 before use. The glass electrode was rinsed with distilled water before being dipped into the samples. The pH was read when digital reading stabilizes. Readings were taken as soon as the metric values stabilized by giving a beep sound [18].

2.2.2. Temperature

A portable calibrated mercury-bulb thermometer (Jenway 3015 model) at the site of sampling was dipped into each water sample and left for about 5-10 minutes and the thermometer was read and recorded in °C [18].

2.2.3. Turbidity

Turbidity of the water samples was determined using the cell riser which was installed in the cell holder of model 2100A Turbidimeter in one of the two highest ranges (100 or 1000 NTU) [19].

2.2.4. Total Suspended Solids

Total Suspended Solids (TSS) is the total amount of suspended particles in sample of water [20].

TSS was calculated using the equation (1) shown below:

$$\text{TSS (mg)} = (A-B) \times 1000/\text{mL of sample filtered} \quad (1)$$

Where; A = Pre-weight of filter paper and B = Post-weight of filter paper.

2.2.5. Total Dissolved Solids (TDS*)*

TDS was determined following the procedure of Richard [21] by using Electrical Conductivity (EC) meter.

2.2.6*.* Chloride Ion Concentration (Cl^-)

Chloride ion concentration was determined using Mohr's method.

2.2.7*.* Total Hardness

Total hardness was determined by adding two milliliter of ammonia solution to 50ml of each sample and little quantity of Eriochrome Blue-Black indicator added. This was then titrated with 0.01M EDTA in the burette [18].

$$\text{Titre value} \times 20 = \text{Total Hardness (mg/l)} \quad (2)$$

2.2.8. Alkalinity

Alkalinity determination was done by measuring 50ml of each sample into a conical flask and two drops of sodium trioxosulphate (II) added to remove traces of chlorine. Three drops of methyl orange indicator was then added and titrated with 0.02N tetraoxosulphate (VI) acid [18].

$$\text{Titre value} \times 20 = \text{Alkanity (mg/l).} \quad (3)$$

2.2.9*.* Electrical Conductivity (EC)

Electrical conductivity measurement should therefore be made in situ (dipping the electrode in the stream or water sample) or in the field directly after sampling. Conductivity determination was performed using conductivity kit Wag WT 3020 by Wagtech International.

2.2.10. Oxygen

(i) Dissolved Oxygen

The determination of dissolved oxygen was achieved using Winkler titration method.

(ii) Biological Oxygen Demand (BOD)

Biological oxygen demand was analyzed from data obtained from flow rate and chemical oxygen demand, using the mathematical expression,

BOD =11000(flow rate x COD) [22](APHA, 2002). (4)

(iii) Chemical Oxygen Demand (COD)

The COD is determined by titration with (0.25M) Ferrous sulphate, using 1:10 phenanthroline [23].

3. Results

Table 1. *Result of Physicochemical analysis.*

Parameters	Boreholes At 9th mile	Enugu urban	Ajalli Stream
pH	6.21	6.18	3.80
Temperature (^{o}C)	27.0	26.0	30.0
Turbidity (NTU)	0.63	1.13	31.96
TDS (mg/l)	12.94	867.93	31.96
TSS (mg/l)	2.70	5.32	59.32
Electrical conductivity (µcm/s)	53.32	63.02	985.67
Dissolved oxygen (mg/l)	4.13	5.85	1.43
Biological oxygen demand (mg/l)	1.33	1.28	10.00
Chemical oxygen demand (mg/l)	4.47	3.75	24.95
Chloride ion concentration (mg/l)	7.67	7.32	154.32
Alkalinity (mg/l)	60.46	71.25	121.87
Total hardness (mg/l)	21.44	17.42	112.57

4. Discussion

Table 1. Represents the results of the physicochemical properties of the water samples from 9th mile, Enugu urban and Ajalli stream. The pH of borehole water from 9th mile corner and Enugu urban fell within the acceptable limit of 6.5 - 8.5 for drinking water according to WHO, while Ajalli stream was slightly acidic and is unsafe for both domestic and industrial use.

The temperature, which is one of the important factors in aquatic environment since it regulates physicochemical as well as biological activities was recorded between 26°C to 30°C.

Turbidity, a very good test for water quality which measures the cloudiness or haziness of fluid caused by particles that may not be visible to the naked eye, and ranged of 0.63 to 31.96 (NTU) was ascertained. The turbidity values of water samples from Enugu and 9th mile of 1.13 and 0.6 NTU respectively are far below the permissible limit of 5.00 NTU, while Ajalli stream exceeded the allowable limit in domestic water. The turbidity value in the water samples might be as a result of increase in the type and concentration of the suspended matter released by the industry. A similar range of result (0.08 to 0.58 NTU) was obtained by Okonko and coworkers [24] in their studies of borehole water and other sample water from sparsely industralised part of Lagos used for domestic purposes in Lagos, Nigeria. The TDS of water samples from boreholes in 9th mile corner, Enugu urban and Ajalli stream were 12.94, 31.96 and 867.93mg/l respectively. The value gotten in Enugu urban and Ajalli stream exceeded the permissible limit in drinking water (25mg/l). TSS concentration in borehole water sample and Ajalli stream may be due to entrance of waste water and effluents in to water distribution network through leakage, improper dumping of domestic and municipal solid waste and weathering of soil.

TSS value of 9th mile corner and Enugu urban were moderate while that of Ajalli stream was slightly high for some domestic use with values of 2.70, 5.32 and 59.32mg/l for 9th mile, Enugu urban and Ajalli stream respectively.

Electrical conductivity of 53.32 and 63.02 obtained from the water sample in 9th mile corner and Enugu urban respectively, though relatively high, may be compared to the electrical conductivity range of 20.50 to 45.50 µs/cm and 18.80 to 60. 00µs/cm obtained by Mishra and Bhatt [25] in their studies of borehole water in Anand District of India, and Lehloesa and Muyima [26] in their study of underground water in the Victoria District of South Africa. These high values could be ascribed to the present of soluble ions in the water samples.

The dissolved oxygen of Ajalli stream (1.43mg/l) was low with respect to International Standard value of 6.00mg/l, perhaps, due to untreated organic and inorganic waste discharged into the stream. Nevertheless, the results fell within the range of what was obtained by Itah and Akpan [27] with values of 0.01 to 2.00mg/l in a similar study of borehole water samples from industralised part of Eastern Obolo Local Government Area of Akwa Ibom State. The dissolved oxygen values of 4.13 and 5.85mg/l for the 9th mile and Enugu urban water samples which very close to the value of 6.0mg/l recommended by international standards.

BOD of the samples ranged from 1.33-10.00mg/l, with Enugu urban having the lowest BOD value, which could be ascribed to the fact that the boreholes are cased and free from organic and inorganic material and waste. The BOD of Ajalli stream suggest high microbial load in the stream which might come from untreated sewage and house hold waste dumped into the stream. The BOD values obtained were quite lower than the WHO recommended standard of 10mg/l. Ogan [28] reported a range of 0.15 to 6.92mg/l at industralised part of Eleme Rivers State, while Ekeh and Sikoki [29] obtained the range of 1.32 to 6.80mg/l from the industralised part of Calabar.

The chemical oxygen demand (COD) of 4.47 and 3.75mg/l obatained from the Enugu urban and 9th mile water samples respectively, were slightly higher than the COD values of 2.9 mg/l reported by Mishra and Saxsena, [30] in their study on water from a boreholes in industrial area of Namibia. While that of Ajalli stream has a slight deviation in COD concentration with value of 24.95mg/l. The COD values of the water samples from Enugu urban and Ajalli stream revealed that the samples are not completely free from inorganic waste.

The chloride ion concentration of 7.67 and 7.32mg/l were obtained in 9th mile and Enugu urban respectively. These values could be from the rock type in the water tables while Ajalli stream has a value of 154.32mg/l which could be from faecal source and some untreated chemical waste disposed in the stream. Chloride in the water sample could be from bedrock cementing material, and connate fluid inclusions. High sodium and chloride levels can result from upward movement of brine from deeper bedrock in areas of high pumpage, from improper brine disposal from peteroleum wells, and from the use of road salt [31]. The ions responsible for hardness of water in the samples were within the acceptable limit for domestic use while Ajalli stream was slightly too high for certain industrial use. The total hardness in the study area ranged from 17.42 to 112.57mg/l.

5. Conclusion

Some physico-chemical parameters on ground and surface water around industrialised part of 9th mile corner, in Enugu State, Nigeria, were successfully determined using standard methods to ascertain the level of water pollution sequel to industrial growth in the area. The results obtained show that despite the rapid industrial growth in and around 9th mile corner of Enugu State, Nigeria, the ground water has not been harmfully affected, and can be used for both domestic and industrial purposes with little or no treatment. The study area provides good business opportunity for manufacturers of beverages and other related products, and is suitably recommendable for such. That of Ajalli stream may need extensive treatment before usage.

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