Spatial Analysis of Industrial Activities and Their Pollution Effects on Sustainable Water Demand in Enugu Environs, South Eastern Nigeria

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Abstract

This study examined the spatial industrial pollution in relation to the sustainability in domestic water demand in Enugu environs, Enugu state in order to identify the Physio-chemical variables that affect the sustainable demand for water use in the study area. The analyses of water samples on the pollution parameters were done with Project Development Authority (PRODA) under the support of the Enugu State Ministry of Environment and Mineral Resources. The results of the analyses were described using descriptive statistics. The results show that the concentration levels of pH, iron, solids, coliform, BOD, etc. increase the rate of water pollution, which affects the biodiversity and sustainability of the environment. However, the values of other parameters such as COD, nitrite, and sulphate are within the permissible levels. They contribute minimally in water pollution and as such do not affect the use of water for domestic purposes within the environment. This gives support to environmental diversity for sustainable development. Therefore, institutional financial support and monitoring via regulatory policies and management strategies should be put in place in order to sustain and protect the environmental diversity for sustainable development.

Keywords: Enugu environs, environmental diversity, permissible levels, physico-chemical pollutants, sustainability, water pollution

Introduction

With increasing economic growth and urbanization, diverse industrial activities take place within the Enugu environment. This has given rise to infrastructural development, availability of varieties of industrial products, employment and income generation which contribute to the welfare of the people. However, the production processes of individual industry require different raw materials that generate varying degrees of industrial by-products or waste (Osibanjo, Daso and Gbadebo 2011). The volume of industrial wastes is growing at an alarming rate, and unfortunately there is inadequate technology, resources and manpower required to effectively manage these wastes in an environmentally safe manner. If the residuals are not utilized via recycling, they become waste, and if discharged into the biosphere, can become pollutants (Chukwu, 2005).

In most Nigerian cities, common means of waste disposal still remain open dumping on water surfaces, land-filling in unlined sanitary landfill sites, open burning, incineration, etc. (Adeyemo, 2003), and water resources seem to face severe quantitative and qualitative threats as pointed out by Abdel – Raouf, Al-Homaidan and Ibrahim (2012). Water represents at least 50% of most living organisms and plays a key role in the functioning of the ecosystem. It is also a critical natural resource mobilized by most human activities. Freshwater resources provide a wide range of goods such as drinking water, and other domestic needs. It is the pillar sustaining development and maintaining food security, livelihoods, industrial growth, and environmental sustainability. Thus, its depletion and pollution affect the environmental diversity as well as sustainable development.

Today, the strategic importance of water and issues concerning sustainable water management is universally recognized, but the pollution increase, industrialization economic growth impose severe risks to availability and quality of water resources in many areas of the world. Water quality degradation is quickly joining water scarcity as a major problem in harnessing the environmental diversity for sustainable development. This is because environmental damage can undermine the future productivity (Chukwu, 2005), and environmental quality itself is part of the improvement in welfare that development attempts to bring (Chukwu, 2005).

The main issue is whether industrial development which heavily relies on the environment as the major provider of raw materials can actually take place without necessarily destroying the environment. Also, in an attempt to continually harness the geographical and ecological diversity of the environment, there is the need to keep to and strictly observe the set environmental laws and standards. This is the reason for evaluating the surface and groundwater quality of the Enugu environs as a result of industrial activities and compares same with WHO/FMENV/NESREA standards. It is generally agreed that industries have impact on the environment because most of them routinely discharge their wastes into the environment. Spatial monitoring of water quality indicators is, therefore, essential for assessing and or protecting the ecosystem in order to harness its diversity of sustainable development. In this study, our objectives are to evaluate the pollution levels of the industrial pollutants and to ascertain their conformity with the standards set by WHO/FMENV/NESREA as a basis for protection of environmental health, safety and sustainability. Also, it is to identify the polluted areas if there are any, for environmental protection and remediation measures for continuity in the possible use of environmental diversity. To achieve these, the study was conducted on different industry types at different locations so that the spatial dimension of water quality for domestic use could be determined.

Description of the Study Area

The study area covers 4 local government areas of Enugu East, Enugu South, Nkanu West and Udi (Fig. 1). It is located within the urban and suburban areas of Enugu environs, Enugu state, Nigeria. Thus, it comprises Emene, Ngwo, Ozalla, Amechi, Umueze communities (Fig.1). It is delimited by latitudes 6^{o} 10´N and 6^{o} 40´N, and longitudes 7^{o} 05´E and 7^{o} 40´E. It is located within the largest city in the south eastern Nigeria and with a population of about 858509 persons according to NPC (2006). Using an approximate annual growth rate of about 2.83% this population was projected to 1,150,059 persons in 2018.

The study area consists of several residential areas and local communities as well as different industries which include oil and gas, rubber processing, iron and steel production, aluminium processing, sachet and bottled water productions, pharmaceuticals, foot mat production, auto- repair workshops, concrete production, plastic and chemical manufacturing. Wastes from these industries are collected and disposed via dumping at dump sites, landfill sites, open burning, incineration, and channelled into nearly streams.

Thus, the quantity of water supplies is declining as a result of pollution in the areas. Water pollution has affected both surface and groundwater in the study area as a result of industrial activities, culminating in the discharge of effluents in the water bodies. Studies show evidence of sewage and industrial effluent contamination. Emodi (2015) carried a study of the impacts of industrial discharges on surface water and found that the impacts of the industrial effluents on the receiving rivers manifested in various dimensions; high level of turbidity (72), presence of dissolved and total suspended solids, high nitrate and chloride levels, increase in phosphorous content, and presence of E, Coli. In these ways both the surface and underground waters are polluted. In these ways both the surface and underground waters are polluted. Water from these sources was investigated for water quality parameters in order to determine their suitability for use especially in domestic needs.

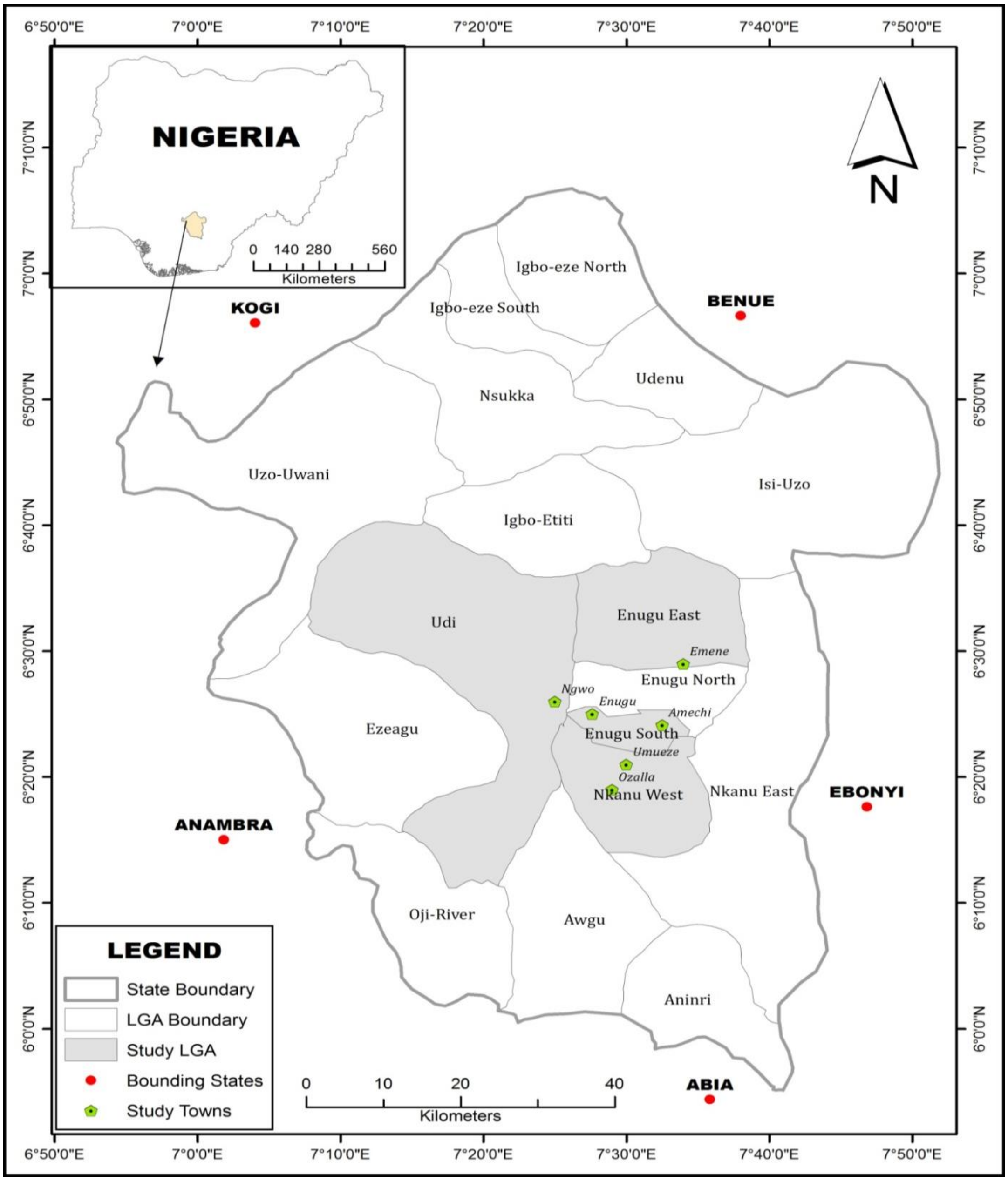

Fig. 1: Enugu Environs showing the study communities
Source: GIS office, Geography Department, University of Nigeria, Nsukka

Literature Review

Industrial processes and water related issues have been the bane of scholarly discussion since the period of the industrial revolution. Water is penitent to industrial production from raw material and final product, transportation, production, manufacturing and effluent discharge. The demand for water for different purposes such as washing, drinking, cooking, etc is affected by untreated effluent from industries. The industrial sector, even though being a key driver of economic growth, also, contributes to critical environmental problem such as water pollution (United Nation (UN), 2019). Kanu and Achi (2011) affirmed the issue of water and industrial effluent in their study on industrial effluent and water pollution. They did a correlation between water bodies and industries by studying effluent from various industries such as pharmaceutical, soap and detergent, paper mill, textile, and brewery. They discovered that effluents from these industries are sources of pollution of water bodies which reduces the quality and subsequent demand and use by humans and livestock. Reza and Singh (2010) studied the water pollution of industries at Augul-Talihar belt of India. The study revealed that the principal sources of water contamination are outlets of industrial discharges and runoff from mining, urban and agricultural practices. Sener, Sener and Davrae (2017) evaluated water quality of the Aksu River in Turkey and its sustainability. Using the water quality index (WQI) method, the result revealed that the source of the main pollutant of the river is a waste from the leather and Mable factories. Bhutani, Kulkammi, Khama and Gantan (2016) monitored the presence of heavy metal around an integrated industrial estate in Haridwan, India. The heavy metals were found to exceed the standard guideline limit. Two major factors that are responsible as revealed by the result of principal component analysis (PCA) are anthropogenic and geogenic in nature. Sayed, Bhuiyam, Chowdhury and Kabir (2015) studied the effects of industrial agglomeration on water quality and discovered that the values of PH, DO, BOD, COD and TDS exceeded the prescribed limits set by the local authority which indicates that the water of Turag River and its peripheral wetlands have been polluted severely and it should not be used in any purpose regarding human and animal life without proper treatment.

In Kumasi Metropolis, Ghana, Danquah (2010) discovered that the pollution of river Aboabo was, among other factors caused by industrial activities which resulted in color, taste, turbidity, odor, and fecal coliform count of the river exceeding WHO Drinking water quality guidelines. This has reduced its quality and yields a significant health effect to people living in the river basin. In Tanzania's major towns and cities, solid and liquid wastes are left untreated. As a result, air and water are contaminated with pollutants, a major health hazard in the area. A study by Mohammed (2003) found that in Zanzibar, faecal coliform and total coliform levels of up to 70/ 100 mI and numerous thousands per ml of seawater, respectively, have been reported in the waters fronting the Zanzibar Municipality. Such pollutants are dyes and paint wastes and strong alkalis (from textile factories); oil, and tars (from vehicle depots and power stations); organic wastes (from breweries and meat plants) (Mohammed, 2003). These pollutants impact heavily in the pollution of many rivers in the country. For instance, Domasa (2018) discovered that Msimbazi River has as high as 12 pH levels.

In Nigeria, water pollution has led to high levels of toxic chemicals such as metals and pesticides, and poor water quality affects people, the economy and the environment (Odume and Slaughter, 2017). Suleiman and Abdulkadir (2017) in their study on consequences of water pollution and the way forward among local communities in Nigeria found that human being is responsible for water pollution by especially dumping of industrial waste into surface water bodies which makes access to clean water a serious problem. They showed that fresh water represents the main sources of safe water for household and agricultural and it is required for drinking, cooking, recreational activities, farming, fishing etc. Aboyeji (2013) added that many water bodies near urban areas in some local communities in Nigeria are highly polluted due to dumping of garbage by individual and dangerous chemicals by manufacturing industries, health centres, schools, and market places.

Even though an industrial effluent always reduces water quality, there are some deviations whereby industrial effluents if treated do not affect water demand. For instance, Tiwani, Demaro, Singh and Mahaths (2015) evaluated the surface water quality using GIS and heavy metal pollution index (HPI) model around the local mining area. Data collected were analyzed using inductively complied plasma mass spectrometry (ICP-MS). The HPI values were below the critical pollution index of 100. The study concluded that the water quality was found to be within desirable limits for domestic uses. Also, Ebachi and Hisorial (2017) studied the quality of physiochemical parameter of River Jajs. The results show that the water quality parameter is considered safe. The main issue, therefore, rests on inadequate treatment of effluent before discharging into water bodies because if the effluents are well treated, it will reduce its detrimental effects on sustainable demand for water on anthropogenic uses. We solicit for proper treatment because of adverse effect of untreated industrial effluent. For instance, Wang and Yang (2016) studied industrial water and health in China. They found that industrial effluent in water affects the mental and physical health of low-income people who might not have money to further purify water before use. It is with this background that this study became necessary in order to identify pollution effects of industrial activities on sustainable water demand for domestic uses in Enugu areas of Enugu State, Nigeria.

Materials and Methods

This study covered mainly Enugu Environs which include the suburban areas of Emene, Ngwo, Ozalla, Amechi, and Umueze communities. The choice of these communities was informed by the nature of water sources available in the area and the activities of the available industries regarding their waste management strategies. Again, 9 closest industrial plants to the water sources in the area were selected. The water sample sites were carefully selected to include boreholes and hand dug wells within and outside the factories, and nearby streams or seasonal streams that are presented in Table 1. Also, Table 1 shows the number of industrial plants that were purposively sampled, their locations, sources of water (the only available water sources from the areas of the sites of the industrial plants), activities involved in each case, and the distances of the sample points (distance of the water sources from each of the sampled industrial plants) from each of the industrial plants. The water samples were collected into 1 liter polyethylene bottles, which were pre-cleaned with concentrated hydrochloric acid and rinsed with distilled water. Also, each container was rinsed with appropriate sample before sample collection. Thus, sterilized rubber bottles were used in the collection of water sample for each point for each of the industrial plants. Each bottle was labelled accordingly before sample collection and all samples were taken immediately to the laboratory for analysis. This means that experimental research design was adopted in this study. The experiment and analyses on the pollution parameters were done with Project Development Authority (PRODA), Enugu under the full support of the Enugu State Ministry of Environment and Mineral Resources.

Table 1: Samples collection, distance and sources of water samples

S/N	Industrial Plant and their code numbers	Location	Source of Water	Type of Activity	Dist. from the Factory Site
1	Innoson Technical and Industrial Co. Ltd (01)	Emene, Enugu East	Seasonal stream	Foot mat	175.4m
2	Beematz Table Water (02)	Ngwo, Udi	Borehole	Sachet and Bottled Water	0.0m
3	Sunchi Integrated Farms Ltd (Extension) (03)	Emene, Enugu East	Stream	Agro-Allied	4.7km
4	General Tyre and Tube Company Ltd (04)	Emene, Enugu East	Seasonal stream	Tyre and Tube Manuf.	160.6m
5	Edeonyia Agrobusiness and Industries Ltd (05)	Umueze, Nkanu west	Hand dug well	Oil and Gas	0.0m
6	Clenzz Aluminum Ltd (06)	Enugu, Enugu South	Afa River	Alum. Roofing Sheets	13.3m
7	Nemel Pharmaceuticals Ltd (07)	Emene, Enugu East	Hand dug well	Drugs Manuf.	200.0m
8	Lolite Energy Ltd (08)	Ozalla, Nkanu West	Hand dug well	Bolts and Nuts Manuf.	0.0m
9	Jio-joe Steel Industries Nig. Ltd (09)	Amechi, Enugu South	Hand dug well	Iron and Steel	0.0m

Source; Fieldwork, 2018

Results of the Findings

The result of the physico-chemical parameters obtained from the assessment of surface water of streams/seasonal streams and underground water of boreholes, and hand dug wells are presented in Table 2. Table 2 shows the mean values of each of the parameters in the industrial plants for comparing with the permissible standards. The recommended pH value for water as prescribed by WHO/FMENV/NESREA ranges from 7.0 to 8.5 mg/l. This implies that the sampled water is too acidic and not suitable for domestic purpose without treatment because all the values are below the standard limit. However, the values lie within the same range, and this is typical of water, which drain similar environment (Obeta and Ajaero, 2010). By this, sustainable use of water from the region for domestic activities is affected. The acidity may be caused by the pollution resulting from the indiscriminate effluent discharges from the factories. Acidic water is highly corrosive, and when water is too acidic, biological life may go into extinction (United Nations Environment Program (UNEP), 2008). The standard prescription by WHO is that the electrical conductivity should not exceed 100US/cm. It is important to remark that the higher values of electrical conductivity lead to higher concentration of other parameters like Total Dissolved Solids (TDS), colour and pH. But high electrical conductivity does not imply any health risk (Njoku, Sampson, Obe and Inwji, 2010).

Table 2: Result of the analysis (physic-chemical parameters of water samples

Chemical Element	Industrial plants									WHO /FMENV /NESREA Limit (mg/l)	Mean	Remark
	01	02	03	04	05	06	07	08	09			
pH	6.5	5.9	6.5	6.5	6.9	5.7	6.2	5.6	6.2	7.0-8.5	6.2	Not safe
Colour	15.0	0.25	15.0	15.0	55	36	0.5	25.0	2.5	5.0-50.0	18.3	Safe
Total solids	3.7	79.6	3.7	3.7	211.3	150	85.8	2.3	15.0	500	61.7	Not safe
Total dissolved solids	3.696	39	3.696	3.696	113.8	56.8	40.5	2.24	23.8	400	31.9	Not safe
Total suspended. Solids	0.04	40.6	0.04	0.04	97.5	78.6	45.3	0.06	34.5	500	33.0	Not safe
Calcium	7.2	6.12	7.2	7.2	50.1	13.03	9.12		8.25	75/180	13.5	Safe
Iron	0.20	0.11	0.20	0.20	0.11	0.11	0.11	0.25	0.11	0.1	0.16	Not safe
Lead	Nil	Nil	Nil	Nil	Nil	Nil	Nil			0.01		Nil
Copper	20.0	Nil	Nil		Nil	Nil	Nil			0.05		Not safe
Zinc	Nil					5.23				1.5		Not safe
Cadmium	16.0	Nil			Nil	Nil		3.4		0.01	9.7	Not safe
Potassium	Nil	48.11			120.01	79.19	66.9		60.7		75.0	Not safe
Sodium	Nil	34.8			89.17	61.03	50.01		42.01	120	55.4	Safe
Chloride/ chlorine	27.991	148.4	27.991	27.991	196.13	193.4	184.3	25.992	142.9	200/250	108.34	Safe
Sulphate	33.18	166.9	33.18	33.18	184.0	256.9	224.6	32.13	202.4	200/250	129.61	Safe
BOD	2.2	9.08	2.2	2.2	10.31	101.01	2.2	21.0	10.05	6.0	17.81	Not safe
COD	18.0	8.25	18.0	18.0	9.12	9.76	18.0	20.0	9.15	30/100	14.25	Safe
Coliform	21.0	Nil	21.0	21.0	120.0	Nil	21.0	56.0	Nil	100MPN/100ml	43.33	Not safes
Nitrate/Nitrite		0.03	0.10	1.10	0.04		0.02	0.10	0.8	10/35	0.31	Safe
Magnesium			0.6	0.6	17.83			0.6	3.4	30/40	4.61	Not safe

Source; Enugu state ministry of environment and mineral resources, and PRODA, 2018

It is the presence of total suspended solids that is harmful because they lessen the ability of water to hold oxygen that is very important for aquatic life. However, the electrical conductivity of the sample water sources falls within the acceptable limit. Again, even as the values of the mean solids are below the standard limits, it is an indicative of prolonged deposition of solids in industrial effluents. This may affect the use of diversity for sustainable development because the continued deposition of solids may result in serious ecological problems such as flooding, especially during heavy rainfall with its devastating economic consequences (Omoleke, 2004). This may also cause taste problems, corrosion or aesthetic problems, and turbidity which affects light penetration as well as eating habits of aquatic life.

The high levels of sulphate in all the samples and mean values though lower than the permissible limit of 200/250 by WHO/FMENV/NESREA, is attributed to increased utilization of cement for building and construction purposes in these areas (Osibanjo, Daso, and Gbadebo, 2011). The presence of sulphate in the water samples is due to evaporation and leaching from soil organic matter. Sulphate has objectionable taste, offensive odour, and leads to corrosion in water pipes.

The concentrations of other non-metals (Table 2) in the area vary and are in each case less than the allowable limits for domestic water use as recommended by WHO/FMENV/NESREA. For instance, the concentration of chloride/chlorine ranges from 25.992 mg/l to 196.13 mg/l in the study area, and its acceptable limit is from 200 mg/l to 250 mg/l. Chlorides are not harmful, but have salty tastes. They also, deteriorate water quality and lead to increase in the amount of bacteria. Nitrite, which is formed during organic matter decomposition is readily oxidized to form nitrate. Nitrates are useful as corrosion inhibitors, preservatives, pigments, and in the manufacture of many organic preservation chemicals. Therefore, as a part of environmental diversity, their continued availability within the permissible standards is contributory to sustainable water resource development for domestic water use in the area.

The metal levels were probably nature influenced by geological environment, weathering processes, and metallurgical activities (Olatunji and Osibanjo, 2012). In all, the concentrations vary from one sample location to another, but while some are found to be lower than the permissible levels recommended by WHO/FMENV/NESREA, the levels of concentrations of others are higher than the standard limits. The mean value of iron is 0.16 mg/l and the acceptable level by WHO/FMENV/NESREA is 0.1mg/l. In the water samples the range, especially of iron is from 0.11mg/l to 0.20mg/l (Table 2). Thus, the water available in the study area is not suitable for domestic purposes. Moreover, there is a high corrosion process of iron containing metallic components and equipment, and high concentration of iron causes brown or black stains on laundry and plumbing fixture. In addition, high amount of iron in drinking water causes turbidity, yellowish colour, and unpleasant taste. Copper and zinc are nontoxic in small concentration. But they cause undesirable tastes in domestic water. However, at high concentrations zinc makes water to appear milky, while copper is malleable and highly resistance to corrosion. Calcium content should be monitored as it increases the hardness in water.

Biological oxygen demand (BOD) is the oxygen-depleting strength of organic matter via the action of decomposers. It is an expression of how much oxygen is needed for microbes to oxidize a given quantity of organic matter. The amount of oxygen needed to achieve this is called the chemical oxygen demand (COD). The BOD of the effluents varies among the 9 sample sites that were studied. It is high and above the demand limits of 6.0 mg/l by WHO/FMENV/NESREA in 5 sample water sources located at Ngwo, Umueze, Enugu, Ozalla and Amechi, while its value is less than the limit of 6.0 mg/l in 4 samples all of which are found in Emene (Table 2). At high levels, it is dangerous to discharge the effluents without aeration as this would deplete the water of dissolved oxygen that is needed by aquatic animals for respiration. This is because high BOD leads to less dissolved oxygen, which is detrimental to aquatic lives, and it is an indication of poor water quality. The high BOD of the effluents could be attributed to only partial or non-treatment of the effluents of the industrial plants before releasing them into the waste-receiving regions. In the extreme, large amounts of organic matter could result in a near-absolute depletion of oxygen, which would make life impossible for the species that need oxygen (Chukwu, 2008). Fish and zoo plankton die under such circumstances, and even among the bacteria themselves, there is a rise in anaerobic species. In this way, the diversity of the environment is affected because fishing industry and all the activities that depend on aquatic life are no longer sustainable.

The COD of the samples ranges from 9.12 mg/l to 20.0 mg/l in all the samples. This means that the industrial plants do not yet meet the standard recommended by WHO/FMENV/NESREA (30-100 mg/l) for sustainable domestic use of water in the area. As such, high amount of oxygen is present in the water (both surface and underground water) found in the study area. The low amount of COD is beneficial to agricultural activities as it reduces the rate of soil nutrient fixation, while increasing the rate of nutrient availability to plants. Also, this process encourages the growth in aquatic lives, which in turn results to sustainable development in the use of plants and animals.

The coliform count ranges from 21.0 to 120.0 MPN/100ml, while the standard limit by WHO is from 0.2 MPN/100ml. It is even absent in some water samples sourced from 3 locations of Ngwo, Enugu, and Amechi. Escherichia coli count ranges from 3 to 29 MPN/100ml) as compared to 0.0 MPN/100ml standard limits by FEPA/WHO. This implies that water from 6 sample sources at Emene, Umueze, and Ozalla in the region is not suitable for drinking and portends danger from waterborne disease like dysentery, diarrhea, typhoid, and hepatitis. Coliform bacteria are a collection of relatively harmful micro-organisms that live in large numbers in the intestines of man and animals (Iro and Chukwudi, 2010). They aid in food digestion. A specific subgroup of this collection is the fecal coliform bacteria. The presence of faecal coliform bacteria and viruses in aquatic environments indicates that the water has been contaminated with the faecal material of man or other animals leading to water-borne disease (Ocheri, Yang, and Ahola, 2008). Thus, a health risk exists for individuals that are involved in the use of such contaminated water for domestic activities especially as drinking water.

Conclusion

This study investigated the spatial qualities of both surface and underground water in Enugu environs in order to determine whether the level of pollution is affecting the sustainable use of water in the area. The levels of some parameters analyzed were above the limits recommended by WHO/FMENV/NESREA for sustainability in the use of water. This study established that the levels of COD, nitrite and sulphate are lower than the levels allowed by WHO/FMENV/NESREA. As such the parameters do not affect the environmental diversity. Sulphate serves as raw material in the pharmaceutical industry, while COD contributes to increase in the rate of availability of nutrients to plants. Conversely, water of the region is acidic, and the level of iron is higher than the permissible limit of 0.1mg/l which makes water unsuitable for domestic purpose. The high BOD in some samples depletes the water of dissolved oxygen that is needed by aquatic animals, but this process leads to the availability of methane, hydrogen sulphide, and ammonia. The high coliform value of 21.0 to 120.0 MPH/100ml makes water unsuitable for domestic use as this portends danger from waterborne diseases. Thus, it will be unsafe to exploit water from the area for use without some form of physical and chemical treatments in order to deal with these impurities.

Recommendations

Based on the findings of the study, the following recommendations are suggested;

i. The study recommends the need to develop an environmental monitoring and management programme in order to monitor water pollution that could endanger the environment, and as well sustain the status of the environment and its diversity for sustainable use.

ii. Continuous monitoring of the physio-chemical variables is important so that the status of those that are safe be maintained, while strict environmental laws are put in place, especially, to check those parameters that make water unsafe for sustainable use.

iii. As this study brought out the area specific and physio-chemical variables that contribute to low water quality, we recommend area specific policy that will address water quality problems of different areas to avoid unnecessary generalization and blanket policies.

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