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Review Article

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Impact of Brewery Effluents on Surface Water Quality in Nigeria: A Review

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Abstract This work presents a review of the impact of brewery effluents on surface water quality in three selected States (Enugu, Lagos and Edo) in Nigeria. Effluents from breweries were found to include waste water from washing bottles, water treatment plant, carbon dioxide generating plant, bottling and production halls and general waste water from domestic washing, sanitary waste of employees, as well as those utilized in various cooling systems, *etc*. The physicochemical parameters analyzed after pollution were: pH, temperature, electrical conductivity, total solids, total suspended solids, total dissolved solids, biological oxygen demand, chemical oxygen demand, dissolved oxygen, turbidity and odour. The extent of surface water pollution by brewery effluents were evaluated using the Federal Ministry of Environment and Urban Development (FMEUD), World Health Organization (WHO), National Environmental Standards and Regulations Enforcement Agency (NESREA) or the in-house effluent permissible limits. Results obtained from Enugu River indicated that nearly all the parameters were within the permissible standards except the dissolved oxygen, total suspended solids, turbidity and odour, which did not comply with NESREA and WHO standards. Parameters of the Lagos Rivers were within FMEUD and WHO permissible limits except biological oxygen demand and trace metal Iron levels which were above maximum permissible limits for aquatic ecosystem by FMEUD and WHO. Similar result was obtained for Edo River except a decline in dissolved oxygen (at the first point), mean turbidity values above acceptable levels of WHO, NESREA, and DPR. All the values of trace metals were lower than the acceptable limits except Cu which is above the acceptable limit. From the review, increased concentration of biological oxygen demand, turbidity, odour and other parameters which were above the permissible limits were recorded and these may have marred the use of these rivers for drinking purposes. Field test results from other researchers were also presented. Recommendations for future study were suggested.

Keywords Brewery effluents, surface water, pollution, aquatic vegetation, physico-chemical properties

1. Introduction

Surface water is any water that collects on the surface of the earth. This includes oceans, seas, lakes, rivers, or wetlands. Fresh surface water is maintained by rainfall or other precipitation, and it is lost by seepage through the ground, evaporation, or use by plants and animals. Man-made bodies of water are not considered surface water since they generally rest on artificial surfaces, not the ground itself [1] which is an important source of domestic water for most rural dwellers in Nigeria. It offers economic support for agricultural irrigation purposes, cooling effects for power generation plants, used in the chemical, steel, breweries, mining and other industrial applications [2]. Surface water such as rivers is regarded as an open system and has been subjected to increased pressure from human activities which often results in irreversible degradation as well as affecting their ecological integrity [3]. It is regarded as the most convenient sewer for industries and municipalities and is the most vulnerable water body to pollution. According to USEPA [4], one of the pollutants, oxygen-demanding wastes, in particular, has been such a pervasive surface water problem as they affect fish and other aquatic life; whilst human lives and other living things are adversely affected by the pathogens, nutrients, heavy metals and volatile organic compounds found in such polluted water bodies. Therefore, surface water quality in Nigeria has been greatly impaired and found unsuitable for beneficial purposes (such as domestic use, irrigation, recreation, wild life, food processing, *etc.*) due to pollution from wastes.

The problems facing Nigerian environment are vast and diverse. Environmentalists have expressed concerns about issues on global warming, depletion of the ozone layer, population growth, destruction of rain forests, air and water pollution, groundwater depletion and contamination. Water pollution is a serious problem globally involving the discharge of dissolved or suspended substances into groundwater, streams, rivers and oceans. Brito *et al.* [5] defined pollution of the aquatic environment as the introduction by man directly or indirectly of substances into the marine environment which results in deleterious effects that are harmful to the living resources in the aquatic environment, hazards to human health, hindrance of marine activities including fishing and impairment of quality for use of the water bodies. A major source of pollution in developing countries is industrial activities and this has gradually increased the problem of waste disposal [6]. Water pollution is a major global problem which requires evaluation and revision of water resource policy at all levels (from international to individual aquifers and wells). It is acclaimed to be the leading cause of deaths and diseases worldwide because Ogbu *et al.* [3] suggested that water pollution accounts for the death of more than 14,000 people daily. Water pollution contributes to the increased BOD by increasing the amount of organic matter present in water bodies, with organic waste containing nitrates and phosphates (additional nutrients), leading to death of plants (excess plants fight for space to grow), which will in turn affect aquatic life. Water pollution causes bio-magnifications through the enhancement in the concentration of various toxic substances along the biological food chain [3, 7].

Increased industrial activities and urbanization in Nigeria have gradually led to increased problem of waste disposal and consequent pollution of surface water from industrial, agricultural and domestic sources [6]. Given the role of carrying off industrial waste, open water systems (rivers) are among the most vulnerable water bodies as they receive directly or indirectly these pollutants. Untreated wastes from processing factories located near cities are discharged into inland water bodies resulting in stench, discoloration and a greasy or oily nature of such water bodies [8]. These wastes pose serious threat to associated environment including human health risks causing diseases [9]. Thus, there is need to control the pollution of surface and ground water since the public health and wellbeing of the people have a direct link with the availability of adequate quantity of good quality water. However, industries such as food and beverages, breweries, metal works, petroleum refinery, soap and detergents, textiles, paints, chemical and plastics, *etc.* produce various amounts of effluents discharged into the environment. They use large volume of water for processing and have the potential to pollute waterways through the discharge of their effluents into streams and rivers or by run-offs and seepage of stored wastes into nearby water resources [2-3]. The pollutants from these effluents have been identified as being responsible for major health and environmental problems such as motor neurone disease [10-11], reproductive disorders and cardiovascular disease [12]. According to Dawodu and Ajanaku [2], cases of minamata disease were reported in Japan, which affects the field of vision, hearing and speech. It can cause in extreme cases paralysis, coma and death as a result of the release of methyl mercury in the industrial effluents of a chemical factory into the water bodies.

Many densely populated cities like Lagos, Port Harcourt, Benin, Kaduna, Enugu, Kano, *etc.* are mostly feeling the impact of effluents from brewery and other manufacturing industries on the quality of public water bodies. Most of the multinational companies in some of these major highly populated Nigerian cities have effluent pre-treatment plants, though with low primary, secondary and tertiary treatment facilities [2]. Therefore, they do not meet the standards of the Federal Ministry of Environment and Urban Development (FMEUD), World Health Organization (WHO), or National Environmental Standards and Regulations Enforcement Agency (NESREA) or even the in-house effluent permissible limits which make the river unfit for consumption by the people living downstream.

With the ever increasing pressure for both statutory and environmental sources to reduce pollution to the barest minimum and save the quality of our water bodies as well as their aquatic habitants, it has become imperative for effective treatment of various brewery effluents before discharge into the receiving streams, or water bodies. In the light of this background, some works have been done on brewery effluent characteristics [13], evaluation and effects of brewery effluents disposal on public water bodies and quality in Nigeria [2, 14]. Having pointed out the many possible water body pollutants, this work therefore, aims at reviewing the available reported works carried out by other researchers on the impact of one of the pollutants (brewery effluents) on surface water quality in some of the major cities in Nigeria, with a view to point out the ecological problems arising from improper brewery effluent management and remediation of effluent-contaminated water bodies and make recommendations for further work.

2. Brewery Effluent Sources and Characteristics

Brewery effluent is the resulting sludge flow from a wastewater system of a brewery. The quantity and quality of brewery effluent can fluctuate significantly as it depends on various different processes that take place within the brewery. The organic components in brewery effluent are generally regarded as biodegradable since these mainly consist of sugars, soluble starch, ethanol, volatile fatty acids, protein, carbon, nitrogen and sulphur as well as solids which are mainly spent grains and waste yeast [15]. Orhue *et al.,* [16] and Ogbu *et al.,* [2] reported that untreated brewery effluents typically contain suspended solids in the ranges of 10-60 mg/l, biological oxygen demand (BOD) (1000-1500 mg/l), chemical oxygen demand (COD) (800-3000 mg/l), nitrogen (30-100 mg/l) and phosphorus (10-30 mg/l). However, not all of the organic materials are dissolved in the effluent hence some organic materials such as spent grain will remain as particulate [6]. Tchobanoglous *et al.,* [15] posits that the most widely used analytical method of wastewater organic characteristics and measures for evaluating the interaction between the amounts of dissolved oxygen used by the living organisms in the oxidation of organic matter and the resultant effect of the carbon dioxide on water for optimum balance within the system are by testing the levels of BOD, COD, total organic carbon (TOC), pH, electrical conductivity (EC), and sodium absorption ratio (SAR).

However, brewery industries are one of the major sources of pollution in all human environments [17]. Generally, the type of industry determines the kind of pollutants that can be discharged directly or indirectly into the environment. Studies have revealed that effluents from brewery waste treatment plants are technically efficient with respect to most of the physico-chemical parameters such as: pH, Chloride, Alkalinity, Calcium, Magnesium and Nitrate [18]. Brewery effluents also include waste water from washing bottles, water treatment plant, carbon dioxide generating plant, bottling and production hall and general waste water from domestic washing, sanitary waste of employees, as well as those utilized in various cooling systems [2, 19]. Brewery effluents can be variable in quantity and composition depending on the nature of products (alcohol and beverage), characteristics of waste discharged (turbidity and acidity), characteristics of the receiving stream (alkalinity and magnesium), and size of the industry. Brewery effluents (e.g. malt and wort) contain toxic and hazardous materials from these wastes that settle in open water as bottom sediments and constitute health hazards to the surrounding population that depend on the water as source of supply for domestic uses [7]. The brewery industry, despite discharging large volumes of highly polluting effluents throughout the year, constitutes an important economic sector of any country [20-21].

According to Fillaudeau *et al.* [20], beer is the fifth most consumed beverage in the world following tea, carbonates, milk and coffee. Brewery plants have been known to cause pollution by discharging effluent into receiving stream, ground water and soil. Water consumption for breweries generally ranges 4-8 cubic meters per cubic meter of beer produced [9]. Effluents resulting from fermentation and filtering are reasonably high in organics and BOD contents though low in volume (>40), accounting for about 3% of total wastewater volume; the fermentation and filtering effluents (<40) account for about 97% of the BOD [22]. Brewery effluent pH averages about 7 for combined effluent but can fluctuate from 3-12 depending on the use of acid or alkaline cleaning agent [23]. Generally, the presence of sufficient oxygen promotes aerobic biological decomposition of organic waste. Increased level of BOD implies low dissolved oxygen which is an indication of high pollution load in the water body. However, it must be noted that effluents from individual process steps vary. For instance, while bottle washing results in a large wastewater volume, it only contains a minor part (>20) of the total organics discharged from the entire brewery processes.

In all these activities, there is production of large quantities of waste which need to be treated before discharge. Study has shown that the quality and kind of waste produced depend on a large extent on the frequency of production and cleaning of the vessels employed in production [24]. When these wastes are not effectively treated before discharge, they could pollute the receiving waters accepting these discharges. The water resources of our planet are basic and very important for survival and existence of any living being. They should be properly and adequately protected from pollution in order to sustain their availability and avert life-threatening situations. In 1978, the UN reported consumable water levels at 2.7% of earth's water with ground water being a major contributor at 1.5% [23]. Present estimates quantify consumable water levels at 1% of the earth's water resources and ground water levels are increasingly being threatened by pollution directly and indirectly [25]. There is the need to sustain the consumable water levels for man. As Ekhaise and Anyasi [26] posited, sustainable utilization of the earth's water is the use of water resources which imposes no cost what so ever on future generations, either through depletion of the resource or through a reduction in its quality.

3. Characteristics of Surface Water

The characteristics of surface water include the following:

3.1. Temperature

This is the average kinetic energy of the molecules in a substance. The temperature of surface water is warmest at the top, and it gets cooler beneath. Surface water temperature varies much more by season as well. Warmer surface water tends to have less oxygen concentration, which can impede the survival of some aquatic lives [23]. Drop in temperature of surface water polluted by different brewery effluents (within the WHO acceptable level) could be as a result of dilution of the effluents with the water and supports the survival of any local population of species of aquatic lives [3] and poses serious health ailment to humans.

3.2. Salinity

This refers to the saltiness of surface water. It measures the amount of dissolved sodium, potassium, and other salts in surface water. Higher salinity leads to denser water, which has an impact on surface water currents. Areas with high evaporation rate have higher salinity and denser water because when water evaporates, it leaves salts deposits behind. The saltiness of any surface water polluted by brewery effluents is determined by the brewed wastes [21]. This is because different effluents contain different quantities of salt deposits. The type of effluent discharged, to an extent controls the level of salt content of the surface water.

3.3. Dissolved nutrients

These are the amounts of various chemicals that are dissolved in surface water. These include nitrogen, phosphorous, oxygen, carbon dioxide, and many more, and they each have different effects on surface water. The presence of nitrogen and phosphorus increase the success of plankton, which is important food for ocean ecosystems. Oxygen is also really important because fish and other sea lives need it to survive [27]. High dissolved oxygen values from brewery effluents usually result in increased total suspended solid and turbidity of the surface water which in turn impedes the refraction of sun rays into bottom of the surface water, thereby preventing/reducing photosynthetic actions of sub-surface vegetation.

3.4. Turbidity

This is a measure of the clarity of surface water to the human eye. Low turbidity means that the surface water is particularly clear. Surface water can be made less clear due to the presence of plankton, sediment levels, erosion rates, and pollution from brewery effluents and runoff from nearby urban areas. Areas with a lot of human activities, like farming, mining, or building works, can cause high sediment levels and lead to poor clarity. The effects of this are mixed. On one hand, high turbidity reduces the amount of light reaching deep into the surface water, which reduces the growth of plants and, therefore, affects the species that eat them. It also can make it hard for species to absorb oxygen. However, there is one benefit to high turbidity: it can provide cover for young members of species, enabling them to hide from predators and survive better [23].

4. Impact of Brewery Effluent on Some Water Bodies

4.1. Brewery effluents on surface water in Enugu State

In Enugu State, Ogbu *et al.* [3] conducted a physico-chemical analysis of the Nigerian breweries effluents and Ajalliowa River in the months of May and June. The physicochemical parameters analyzed after pollution were: pH, temperature, electrical conductivity, total solids, total suspended solids, total dissolved solids, biological oxygen demand, chemical oxygen demand, dissolved oxygen, turbidity and odour using standard methods for evaluation of water and wastewater [28-32]. The values obtained in their study (Table 1) were compared with international and national standard values for water and wastewater [33-34]. Nearly all the parameters were within the permissible standards except the dissolved oxygen, total suspended solids, turbidity and odour, which does not comply with NESREA and WHO standards. Also electrical conductivity of the effluent was only higher than the permissible standard of WHO in the month of June. NESREA standard for electrical conductivity was not stated but the conductivity of the river was within the standard of WHO for both months. Both the brewery effluent and Ajalliowa River gave an objectionable odour, which is unsatisfactory going by WHO and NESREA standards for odour.

Table 1: Physico-chemical characteristics of the brewery effluents and surrounding surface water body (Ajalliowa River) [3]

Parameter	Brewery Effluent		Ajalliowa River		Permissible Limits	
	Mean	Range	Mean	Range	WHO	NESREA
pH	7.71 ± 0.15	7.66 - 7.76	7.69 ± 0.00	7.69 - 7.69	6.5 - 8.5	6 - 9
Temp ^{0}C	29.50 ± 0.50	30.00 - 29.0	26.00 ± 0.00	26.0 - 26.0	12 - 25	40.0
EC (us/cm)	489.00 ± 172.00	317 - 661	280.00 ± 22.00	258 - 302	400	NS
TSS (mg/L)	26.75 ± 0.25	27.01 - 26.50	47.01 ± 0.99	46.02 - 48.00	NS	25
TDS (mg/L)	2.55 ± 0.47	2.08 - 3.02	1.86 ± 0.24	1.62 - 2.10	50	500
TS (mg/L)	29.31 ± 0.51	29.09 - 29.52	48.87 ± 0.11	47.64 - 50.10	1000	NS
BOD (mg/L)	1.95 ± 0.100	2.08 - 1.85	1.52 ± 0.12	1.64 - 1.40	40	30
COD (mg/L)	49.97 ± 6.00	43.97 - 55.97	10.94 ± 2.97	13.92 - 7.97	80	60
DO (mg/L)	3.00 ± 0.15	3.15 - 2.85	4.37 ± 0.17	4.54 - 4.20	7.5	NS
Turbidity (NTU)	388.00 ±117.00	50.5 - 27.1	278.00 ± 33.00	311 - 245	5.0	5.0
Odour	Objectionable	Objectionable	Objectionable	Objectionable	Odourless	Odourless

Note: Temp = temperature, EC = electrical conductivity, TSS = total suspended solids, TDS = total dissolved solids, TS = total solids, BOD = biological oxygen demand, COD = chemical oxygen demand, DO = dissolved oxygen and NS = not stated.

The pH range of freshwater is known to be between 6 and 9. The pH of wastewater needs to exceed this range in order to protect and be beneficial to aquatic organisms, and also 7 for drinking water [3, 30, 33]. From Table 1, the pH values obtained were slightly higher than the pH of water (neutral-7). This could be as a result of the detergents used for washing that formed part of the brewery effluent. However, the values were within the permissible limits of NESREA and WHO of 6 – 9 and 6.6 – 8.5 respectively. Therefore, the pH of the surface water poses no life threat to people using the water for domestic purposes as well as and the aquatic habitants. This observation corroborated with the findings of [6, 13, 26, 32, 35-36] for Niger Delta, Ikpoba River, Najawe, Enugu, Ibadan and Ogun River respectively.

In addition, all the temperature values obtained were within NESREA (2009) permissible limits for effluent discharges to surface water but did not meet the WHO standard (12 – 25^{o}C) and hence would have a negative impact on the water quality; a temperature of 26 ^{o}C was maintained. This could be due to dilution as the brewery effluents mix with the surface water (Ajalliowa River). This follows the trend of the results of Alao *et al.* [6]; Olorode and Fagade [14] who reported 24 – 27 ^{o}C temperature range. The result of EC was within WHO range except the brewery effluent of the month of June. This is an indication of danger and threat to aquatic organisms and habitants as well as unsuitability for drinking purpose. The amount of chloride (Cl^-) ions present in water has direct link to the conductivity of brewery effluents [3]. In other words, the conductivity of Cl^- is proportional to the conductive capacity of brewery wastewater. Conversely, corrosion of iron pipes and plates can be caused by excessive Cl^- ions [37]. High amount of dissolved ionic inorganic substances can be found in open surface drinking water (like the Ajalliowa River) if the brewery effluent that is high in conductivity gets into it. This may result in water imbalance problems for aquatic organisms and could grossly reduce the level of dissolved oxygen [3]. From Table 1, a higher EC value (661 us/cm) of the brewery effluent had a corresponding lower value in the month of June when discharged into the River as a result of dilution with fresh river water which neutralizes the high chlorine (Cl^-) ions content of the brewery effluent. The TSS of the River and the brewery effluent were above NESREA permissible limits. This could be attributed to materials used for brewing such as waste yeast, grit, spent hops, mash, spent grains and other inorganic substances. These values may impede the survival of aquatic habitants by reducing their food availability, and light penetration which leads to decrease in photosynthesis [3]. Documentaries on brewery effluents and management [30] stated that high TSS values in surface water can create anaerobic conditions and suffocation for aquatic lives. However, TSS is used to evaluate surface water quality. TSS of the Ajalliowa River shows compliance with the limits of WHO and NESREA and has similar results with Egwuonwu *et al.* [32], Dimowo [36].

The biological oxygen demand (BOD) of surface waters is the most widely used parameter in evaluating its organic pollution [3, 32]. It is a 5-day measured value of the amount of dissolved oxygen taken up by aerobic micro-organismsto degrade oxidizable organic matter contained in open surface waters. The values of BOD of the brewery effluents and the Ajalliowa River recorded were satisfactory and within WHO and NESREA permissible limits [33,34]. This inferred that the amount of biodegradable organic matter in the brewery effluent was low and the dilution by the river water tends to reduce dissolved oxygen-demanding substances. Similarly, the chemical oxygen demand (COD) of surface water can be said to be a measure of the equivalent amount of oxygen required to completely oxidize both bio-degradable and non-degradable organic and inorganic substances [3]. The COD values of the brewery effluent and surface river water were within the prescribed limits of WHO and NESREA for effluent discharges to surface water. Hence, there is no effect of brewery effluent on the Ajalliowa River. Similar result by Egwuonwu *et al.* [32] corroborated this observation. The values of dissolved oxygen (DO) of both sampling points (effluents and river water) were found to be within the WHO permissible limits due to increase in TSS and turbidity from the brewery effluent, which inhibits the sunlight from reaching the submerged aquatic vegetation, thereby affecting photosynthesis. This agrees with the findings of Ikpeaiyada and Onianwa [38], Alao *et al.* [6] and Dimowo [36] who reported lower values of DO in the various rivers. Decline of DO could have serious implication for the health of aquatic organism in Ajalliowa River, because low dissolved oxygen reduces or eliminates sensitive fishes and invertebrate species [3]. It may also lead to migration of aquatic organism. USEPA [30] recommends that any water body that maintains aquatic life should contain 5 mg/l of dissolved oxygen for at least 16 hours of the day and the other 8 hours should not drop below 3 mg/l. Based on this, the brewery effluent had marked effect on the DO of Ajalliowa River water. The turbidity values measured at the effluent discharge and receiving river show higher values than the acceptable limits. The murky appearance of the effluent discharge is attributed to the ingredients used in brewery industries such as cereal, adjuncts, hops and yeast. All these combine with water to form wastewater which is discharged directly into the receiving river. The murky appearance of the River may also be due to the above reason in addition to other suspended solids such as clay and silt emanating from soil erosion. Hence, the turbidity in Ajalliowa River can inhibit light penetration needed by submerged aquatic vegetation and thus affects primary production. Organisms directly or indirectly that are dependent on aquatic primary production may also be affected. It can also affect the ability of fish gills to absorb dissolved oxygen.

Moreover, the high turbidity of this River which is used as drinking water could increase the risk of gastrointestinal diseases in people that use the river especially for persons with low immunity, who are susceptible to pathogens attached to the suspended solids. Ecologically, the level of turbidity in Ajalliowa River can negatively influence photosynthesis, decrease primary production and affect fish abundance [3, 32, 36]. This finding agrees with the reports of Ekhaise and Anyasi [26] and Alao *et al.* [6], (for Ikpoba and Majawe Rivers respectively) that showed high turbidity values in different surface waters receiving brewery effluents.

The odour of the Enugu brewery effluent and the AjalliowaRiver samples were objectionable (although no specific method of measurement was stated). This could be as a result of dissolved organic and inorganic compounds such as nitrogen, sulphur and phosphorous which evolved from putrefaction of proteins and other organic materials [3, 39]. Also certain gases (hydrogen sulphide and ammonia) found in brewery wastewater can cause odour, be toxic and pose asphyxiation hazards. This observation is in line with the reports of Breweries of Egwuonwu *et al.* [32].

4.2. Brewery effluents on surface water in Lagos State

Nigeria Breweries Plc. Lagos discharges its effluent into a surrounding water body called Lagos Lagoon. The Lagos lagoon complex is the largest lagoon system of the Gulf of Guinea coast in West Africa [40]. This lagoon system borders the rain forest belt and receives a number of major rivers and streams. In Nigeria, over 85% of the industries are situated in Lagos metropolitan area [41] and their effluents ultimately get into the Lagos lagoon complex directly or indirectly via drainages or streams and pollute the nursery grounds of both fishes and shrimps [42-43]. The mean of each parameter values of the physico-chemical impact analysis of effluents from Lagos brewery discharged on to major streams (Alaka and Agidingbi) are presented in Table 2. The mean pH value of Alaka and Agidingbi streams are 6.54 and 5.9 respectively. However, the pH value of Agidingbi stream is lower than that of the Alaka stream and below the permissible limits of the Federal Ministry of Environment and Urban Development (FMEUD) and WHO for surface waters, which indicates it is acidic. This acidic nature could be as a result of both industrial discharges and domestic waste disposal along the course of the stream. The mean temperature of the streams are 26.97and 27.17 ^{o}C respectively which are below permissible limits. This could be partially related to the effect of shading trees which preclude direct sun radiation along the stream course [2]. The mean conductivity of the two streams ranges from 17.04 to 18.84 µs/cm. These values depict low corrosion potential and are within WHO acceptable limit. This therefore suggests low total dissolved solids levels in boiling and cooling water demineralized section of the brewery industries. The alkalinity values of the streams were found to be 204.8 and 205.9 1mg/l respectively which are within WHO permissible limit for alkalinity. The TSS from the two streams are higher than that obtained from Enugu brewery. These observed high concentrations are pointers to the fact that there are intense anthropogenic activities such as releasing of CO_2, through burning etc. along the course of the streams.

Also the low value of COD observed at the streams could be ascribed to waste discharges high in organic matter and nutrient along the course of the streams. Increase in the BOD concentration of the streams could be related to effluent high in degradable organic matter from brewery and unregulated domestic dumpsites along the course of the two streams.

Table 2: The mean values of physico-chemical and metal analysis of effluents from Lagos brewery

	Locations					
	Alaka stream		**Agidingbi stream**			
Parameters	**Mean**	**Range**	**Mean**	**Range**	**FMEnv**	**WHO**
pH	6.537	0.63	5.9	0.5	6 – 9	6.5 – 8.5
Temperature (^{o}C)	26.97	1.1	27.167	1.0	<40	--
Conductivity (µs/cm)	18.84	0.6	17.043	0.5	--	400
Turbidity (FTU)	5.333	2	6.8	0.6	--	5
Acidity (mg/l)	4.167	0.7	3.8167	0.6	--	--
Alkalinity (mg/l)	204.8	98.1	205.91	97.92	--	500
Total hardness (mg/l)$CaCO_3$	134.3	2.08	137.64	11.81	--	500
Total solids (mg/l)	450.9	85.15	55.79	97.07	---	1000

Total suspended solids(mg/l)	119.4	3.7	120.34	3.85	--	--
Total dissolved solids (mg/l)	566.1	35.19	518.57	85.21	2000	1500
Biochemical oxygen demand (mg/l)	43.08	5.38	41.82	0.53	50	<40
Chemical oxygen demand (mg/l)	55.84	1.95	63.96	5.84	80.1	80
Dissolved oxygen (mg/l)	1.25	1.24	1.2567	1.17	7.5	7.5
Chloride (mg/l)	70.09	9.13	75.077	13.24	600	600
Nitrate (mg/l)	2.777	0.39	2.6367	0.12	20	10
Sulphate (mg/l)	6.897	0.64	6.2333	0.63	500	400
Zinc (mg/l)	1.25	1.16	0.95	0.48	--	5
Manganese (mg/l)	0.117	0.15	BDL	BDL	5	0.5
Iron (mg/l)	0.437	0.58	0.4333	0.84	--	0.3
Copper (mg/l)	0.457	0.49	0.6833	0.32	<1.0	1.0
Chromium (mg/l)	0.023	0.01	0.02	0.0	<1.0	0.05

*BDL = Below Detection Level.

Extracted from: Dawodu and Ajanaku [2].

The locational variation in concentration of trace metals namely; iron, manganese, zinc, copper and chromium in the two surface waters are as presented in Table 2. The source of these trace metals could possibly not be from the brewery rather it may be from other factories that discharge their effluents into the lagoon. However, iron was dominant in both water samples with values of 4.37 and 4.33mg/l for Alaka and Agidingbi streams respectively which are above the acceptable level of WHO (0.3 mg/l) for Iron. This is attributed to a result of the anthropological inputs, as also demonstrated in the result of Egwuonwu *et al.* [32]. However, other metals such as Mn, Zn, Cu and Cr have concentration values much lower than WHO and FMEUD permissible limits. In the Agidingbi River, Mn concentration was below detection limit (BDL) of the instrument. That a metal concentration in the aquatic environment is low and considered to be naturally occurring does not mean that the concentration could not cause adverse ecological effects [2, 11, 30, 44]. Eisler [45] opined that the presence of one metal can significantly affect the impact another metal may have on an organism. The effect can be synergistic or antagonistic.

In general, the study on the impact of Lagos brewery effluents on its surrounding surface waters is characterized by pH in the range of FMEUD and WHO permissible limits. The values of TSS and COD of the two rivers are low and within acceptable limits. Whilst that of BOD and trace metal Iron levels are above maximum permissible limits for aquatic ecosystem by FMEUD and WHO; indicating that the physiochemical condition of the rivers have been influenced by the various effluents. This could result in habitat destruction and alteration of species diversity. Dawodu and Ajanaku [2] suggested that it is imperative for the Lagos breweries to set up effective measures using the best available technology to treat their effluents before discharge to the natural receptors.

4.3. Brewery effluents on surface water in Benin, Edo State

Ogbeibu and Edutie [46] studied the effects of brewery effluents on Ikpoba River in Benin at three sampling stations/locations. Results of the impact of discharged effluents on Ikpoba River were compared with the Federal Ministry of Environment (FMEnv) and Department of Petroleum Resources (DPR) limits for inland waters receiving effluents from brewery industries (Table 3).

Table 3: Summary of physiochemical parameters of Ikpoba River [14]

Parameters	Mean ± S.E	Mean ± S.E	Mean ± S.E	FEPA/DPR limits
	1	2	3	
Air temp. (^{o}C)	27.07 ± 1.1	28.69 ± 68	28.43 ± 1.4	--
Water temp. (^{o}C)	26.47 ± 0.51	30.19 ± 1.49	26.71 ± 0.84	--
Turbidity (NTU)	124 ± 25.8	610 ± 276.5	183 ± 64.77	124 – 610
TDS (mg/l)	42 ± 7.2	174.6 ± 9.8	156 ± 86.2	2000

DO	5.22 ± 0.56	1.84 ± 0.44	3.71 ± 0.35	--
BOD	1.17 ± 0.53	1.17 ± 17	0.99 ± 0.29	30
COD	16.67 ± 6.48	14.9 ± 2.4	12.09 ± 1.7	--
Conductivity (µs/cm)	94.3 ± 15.8	187.6 ± 81.0	64.7 ± 25.9	--
pH	5.54 ± 0.29	4.86 ± 0.33	5.3 ± 0.24	9
HCO_3	94.1 ± 15.39	316 ± 114	52.3 ± 10.7	--
P	1.2 ± 0.38	1.87 ± 0.63	0.60 ± 0.23	5
NH_4	5.54 ± 4.07	4.09 ± 1.9	2.4 ± 0.89	0.2
NO_3	0.0079 ± 0.016	0.014 ± 0.007	0.008 ± 0.0012	20
NO_2	0.003 ± 0.0004	0.0061 ± 0.002	0.005 ± 0.002	--
SO_4	0.4 ± 0.17	0.084 ± 0.03	0.13 ± 0.07	500
Cl	111.7 ± 39.0	111.6 ± 31.9	90.4 ± 25.4	600
Na	3.21 ±1.16	37.1 ± 15.5	2.37 ± 0.73	5
K	3.98 ±1.39	7.25 ± 2.42	2.07 ± 1.09	75 – 200
Ca	15.71 ±4.25	11.22 ± 1.9	9.94 ± 1.86	200
Mg	8.56 ±4.34	6.8 ± 4.17	5.64 ± 1.64	200
Fe	1.088 ± 0.0	0.578 ± 0.21	0.23 ± 0.08	20
Mn	0.27 ± 0.107	0.26 ± 0.14	0.28 ± 0.105	0.5
Zn	0.046 ± 0.01	0.036 ± 0.08	0.032 ± 0.0095	<1
Cu	1.39 ± 0.98	1.25 ± 0.6	0.67 ± 0.26	<1
Cr	0.056 ± 0.011	0.044 ± 0.09	0.034 ± 0.017	--
Cd	0.09 ± 0.04	0.088 ± 0.05	0.058 ± 0.03	<1
Hg	0.002 ± 0.004	0.0022 ± 0.00039	0.0024 ± 0.0005	0.05

When compared with the results of Enugu and Lagos breweries with respect to WHO and NESREA permissible limits in Table 1, the pH of the Ikpoba River which is ranged between 4.86 and 5.54, is below that obtained for Enugu and Lagos breweries, and below the acceptable limits of WHO and NESREA (neutral level) while brewery industries in Nigeria is an encouraging phenomenon from the economic perspective, their wastes should be effectively treated and properly managed, as the general physicochemical results showed that there were slight irregularities and inconsistencies in the effective management of their effluent discharges. This implies that the pH of the surface water poses serious threat to both the aquatic organisms and people using the water for drinking purposes. In reference to WHO guideline values (12 – 25^{o}C) the Lagos and Benin brewery effluents had negative effect on the surface waters since their (rivers') temperatures are above the acceptable limit, but within the permissible limits of NESREA. The mean temperature of the three locations of Ikpoba River ranged 26.7–30.19 ^{o}C. From Table 3, there was a drop in the temperature value of location 2, which could be as a result of dilution when the effluents from locations 1 and 3 mix with the river. The observation is similar with the results of Alao *et al.* [6] who reported 24 -27^{o}C temperature range. The mean electrical conductivity (EC) of Ikpoba River (64.7 – 187.6 µscm^{-1}) is far above that obtained from Lagos (18.4 and 17.043 µscm^{-1}) and higher than that from Enugu brewery (280 µscm^{-1}). All these EC values however, were within WHO standards (400 µscm^{-1}). It implies that the electrical conductivity of the riversis low except that of Enugu (Ajalliowa River). This is as a result of low presence of chloride ions in the rivers [3] from dilution with freshwater. The TSS of Ikpoba River in Benin was not determined for any reason, but that of Enugu (47.01mgl^{-1}) and Lagos rivers (119.4 and 120.34mgl^{-1}) were above NESREA standards. This is because of organic (mash, spent grains, waste yeast, *etc.*) and inorganic materials used in the breweries. These high TSS values may decrease the light penetration ability of the rivers which lead to reduction in the photosynthetic action of the aquatic plants and gross reduction in food availability as well as creating anaerobic and unfavorable conditions which suffocate aquatic lives and reduce the tendency to support aquatic life diversity [30]. As stated earlier, the empirical index of surface water freshness is evaluated using TDS. The mean TDS value of location 1(42 mgl^{-1}) in Benin surface water was observed to have significantly dropped in comparison with those for locations 2 and 3 (Table 3). This is because location 1, which is the upstream of the brewery discharge point has higher pollution index (i.e. low TDS value) than the other locations. The Enugu and two Lagos rivers have mean TDS values of 1.86, 566.1 and 518.57mgl^{-1} respectively. The mean TDS values of the studied rivers are within the permissible limits of WHO, NESREA and FMEnv. The findings of Ademoroti [47]; Egwuonwu *et al.* [32] and Dimowo [36] were corroborated. The mean BOD values of the Lagos Rivers were above the acceptance limits of WHO, NESREA and FMEnv for effluent discharges to surface water (Tables 1 and 2). This indicates thatthe high amount of biodegradable organic matter in the brewery effluents and the dilution by the river waters tend to increase the dissolved oxygen-demanding substances. The reverse is the case for the Enugu River, where low mean TDS value was obtained.

In relation to BOD, the different sampling locations of the Benin River recorded least concentration of COD value followed by the Enugu River and highest in the Lagos Rivers. All these values were within permissible limits of both WHO, NESREA and FMEnv. The results of Egwuonwu *et al.* [32] and Ogbeibu and Ezeunara [14] followed similar trend. The permissible limit of WHO, NESREA and FMEnv for DO was 7.5 mgl^{-1} [14]. Enugu River and the first and third sampling locations of Benin River had values fairly within acceptable limit (Tables 1 and 3), whereas the first sampling point of Benin river and the two sampling points of Lagos Rivers showed a declined value of DO. This agrees with the results of Aloa *et al.* [6] and Dimowo [36] who reported lower values of DO in their study. According to Ogbu *et al.* [3], decline in DO could have impeded the survival of aquatic organisms at the locations of these rivers. This, therefore, implies that these locations of the rivers cannot maintain aquatic lives, hence a marked effect of the breweries effluent on the rivers. The mean turbidity values of Enugu Lagos and Benin rivers were above the acceptance levels of WHO, NESREA and DPR -5.0NTU (Tables 1, 2 and 3). This high turbidity of the rivers from brewery wastes could mar their use for drinking since they pose the risk of gastrointestinal diseases in persons of low immune system. This finding was in line with the reports of Ekhaise and Anyasi [26]; Alao *et al.* [6] and Egwuonwu *et al.* [32].

The locational variations in concentration of trace metals like Fe, Mn, Cu and Cr in Ikpoba River (Benin) were higher than those of Alaka and Agidingbi Rivers (Lagos) (Tables 2 and 3). The concentration of Zn in Lagos River was found to be lower than that of Benin. All the values were lower than the permissible limits of FMEnv except Cu which is above the acceptable limit (<1). As earlier stated that the concentration of any of the trace metals can significantly affect the impact (synergistically or antagonistically) of another on an organism. The concentrations of non-metals (Ca, K, Na, Cl, etc.) and gases (NH_3, NO_3, SO_4, NO_2 etc.) were all within the permissible limit of FMEnv (Tables 2 and 3). The values of chloride concentration in Lagos and Benin rivers indicate absence of salt water intrusion in the surface waters. Other gases such as nitrate, nitrite, etc. indicate that the surface waters may not induce methaemoglobaemia in babies less than six months old [2].

5. Conclusion

The impact of brewery effluents on surface water quality in Enugu, Benin and Lagos was reviewed with a view to point out the ecological problems arising from improper brewery effluent management and remediation of effluent-contaminated water bodies. The extent of pollution by brewery effluents were evaluated using the acceptable limits of WHO, NESREA, FMEnv and DPR. The Ajalliowa, Ikpoba, and Alaka and Agidingbi Rivers are natural receptors of brewery effluents in Enugu Benin and Lagos States respectively are slightly impaired and may have negative effects on both human and aquatic lives. Given their high turbidity values that mar their use for drinking purposes could cause some diseases in humans.

However, while brewery industries in Nigeria is an encouraging phenomenon from the economic perspective, their wastes should be effectively treated and properly managed, as the general physicochemical results reviewed showed that there were slight irregularities and inconsistencies in the effective management of their effluent discharges. However, studies on the impact of brewery effluents on both surface and ground waters for the different seasons in Nigeria is recommended for future studies.

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