

Abstract

The impact of gaseous emissions from the 'E' flow station on the Oguta Lake ecosystem and its associated tributaries was investigated by measuring gas concentrations over a one year period using digital gas analyzers. These results show that the mean concentrations of SO_2 , NO_2 , CO , NH_3 , H_2S and CH_4 at the 'E' flow station were 16.67, 0.69, 12.33, 2.97 and 4.02ppm respectively, while these concentrations at Oguta Lake were 0.29, 0.25, 5.29, 0.16, 0.3 and 0.9ppm respectively. The results indicate that SO_2 and NO_2 concentrations at the 'E' flow station and Oguta Lake do not meet ambient air quality standards [1] and thus constitute a threat to the lake and its watershed. Apart from direct health impacts such as

Impact of Gaseous Emissions from 'E' Flow Station on Oguta Lake and its Associated Tributaries, Niger Delta Basin, South Eastern Nigeria

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respiratory illnesses, poor visibility and aggravation of asthma (which fishermen and other lake users might face), some of these gases (SO_2 and NO_2) cause the formation of acid rains. The slightly acidic nature of Oguta Lake and its associated tributaries is attributed to gaseous emissions from the nearby 'E' flow station and this is inimical

to the sustainable development of the lake in terms of water supply, tourism and fisheries development. The use of scrubbers and the construction of a gas re-injection plant at the study area would serve as respectively short and long term remediation measures.

Keywords: Acid rain, Ambient air quality, Gas analyzers, Gas reinjection plant, Scrubbers.

1. Introduction

The Oguta Lake is the largest natural fresh water resource in the State of Imo, Eastern Niger Delta Basin, South Eastern Nigeria. It is located on an elevation of about 50m, precisely within the latitudes of $5^{\circ} 41'$ and $5^{\circ} 44'$ North and the longitudes of $6^{\circ} 45'$ and $6^{\circ} 51'$ East (Figure 1). The lake originated as an ox-bow shaped lake from Orashi River during the Late Quaternary Glaciation of the northern high latitudes which corresponds to the Pluvials in the Tropics [2]. Orashi River witnessed an incised meandering that continued to swell out into a broad loop with a gradual narrowing of its neck that was later cut off into a large ox-bow lake (Oguta Lake) during the 12,000-7,000 years of the Pluvial Age. The current linear shape of the lake which masks the initial

ox-bow shape may be the result of active erosion at Njaba River end. Satellite imagery reveals the presence of an ox-bow lake in the Oguta area. The surface area of the lake during the dry and wet seasons is measured at 1.8 and 2.5km², while the maximum depth of the lake is 8.0m. The lake has a mean depth and shoreline length of 5.5m and 10km respectively [3]. The lake's annual water storage is estimated at 16,185,500m³ while the portions currently covered by water and eutrophication represent respectively 60% and 5% of the lake's total area [4]. Gaseous emissions, especially SO_2 and NO_2 , from the nearby 'E' flow station flare site are capable of forming an acid rain deposition within and around the Lake, thus reducing the pH of the lake and even that of its associated rivers. The mean pH of the Lake is 6.06 which indicates that it is slightly acidic [5, 4]. This calls

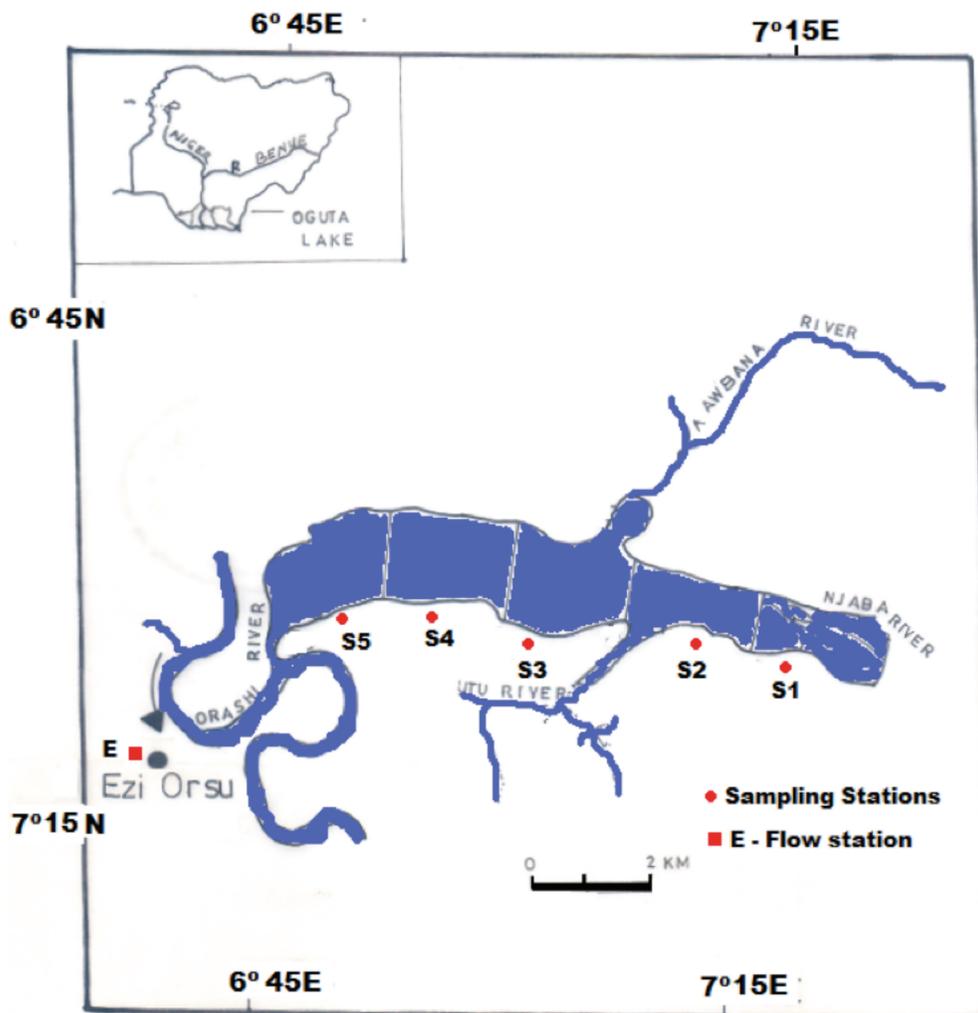


Figure 1. Map of the study area showing sampling locations

for constant monitoring of the ambient air quality at the 'E' flow station flare site, as well as within and around the lake.

The continuous flaring of gases at flow stations in the Niger Delta Basin constitutes a threat to the ambient air quality in the area.

Oguta Lake is of tremendous benefit to both the local community and surrounding areas, as well as to the Imo State government. To the former, it serves as the main source of domestic water supply in addition to its use for transportation, recreation, fishing and sand mining activities. To the latter, it constitutes a focal point for research, sustainable tourism and sports development. In view of this, there is a pressing need to preserve the resource state and usefulness of the lake. Apart from the

regular physical and bio-chemical monitoring of the resource, another important approach to the preservation of the resource and sustainable use of the lake is the constant monitoring of ambient air quality around and within the Lake's ecosystem.

2. Climate and Vegetation

The study area is located within the equatorial rain forest belt of Nigeria. The mean monthly temperature of the area ranges from 25 to 28.4°C while the mean annual precipitation averages 3,000 mm. Most of the rainfall is recorded between the months of May and October [6]. The wet season (May-October) is characterized by moderate temperatures and high relative humidity. The dry period (November to April) is characterized by scanty

precipitations, high temperatures and low relative humidity [6]. The prevailing wind directions in the Oguta area are mainly south-west, north-west and west. However, the south-west wind direction is the strongest [7]. The plant cover of the area includes shrubs and income-generating trees such as oil palm (arecaceae), Indian bamboo (bambusae), avocado pea (*Persia Americana*), African bread fruit (*Trelulia Africana*), oil bean (*pentaclethra mahophlla*) and raffia palms (*raphia ruffia*). Due to the relatively steep shoreline and significant water current, aquatic *macrophytes*, especially the floating and rooted submerged vegetation, are sparse. The 10km shoreline is largely lined with a community of bank *macrophytes* consisting of grasses such as *Panicum sengalense*. The Orashi River end of the lake hosts a

sparse population of floating *macrophytes* such as *Pistia stratiotes*, *Azollia Africana*, *Salvinia auriculata*, *Ceraphyllum demersum* *Ulycularia inflexa*, water lilies-*Nymphyaea lotus*, *N.Macrantha*. Plant life is poor and restricted to the littoral zone (<1.5m depth). This consists of *Crinum natan* and some unidentified grass with very fine leaves [3].

3. Geological Setting and Hydrology

The study area (*Figure 2*) lies within the Niger Delta basin of Nigeria which consists of three major litho-stratigraphic units, namely (from top to bottom) the Benin, Agbada and Akata Formations. The modern Niger Delta started its growth after the Paleocene transgression which was subsequently followed by a cycle of depo-

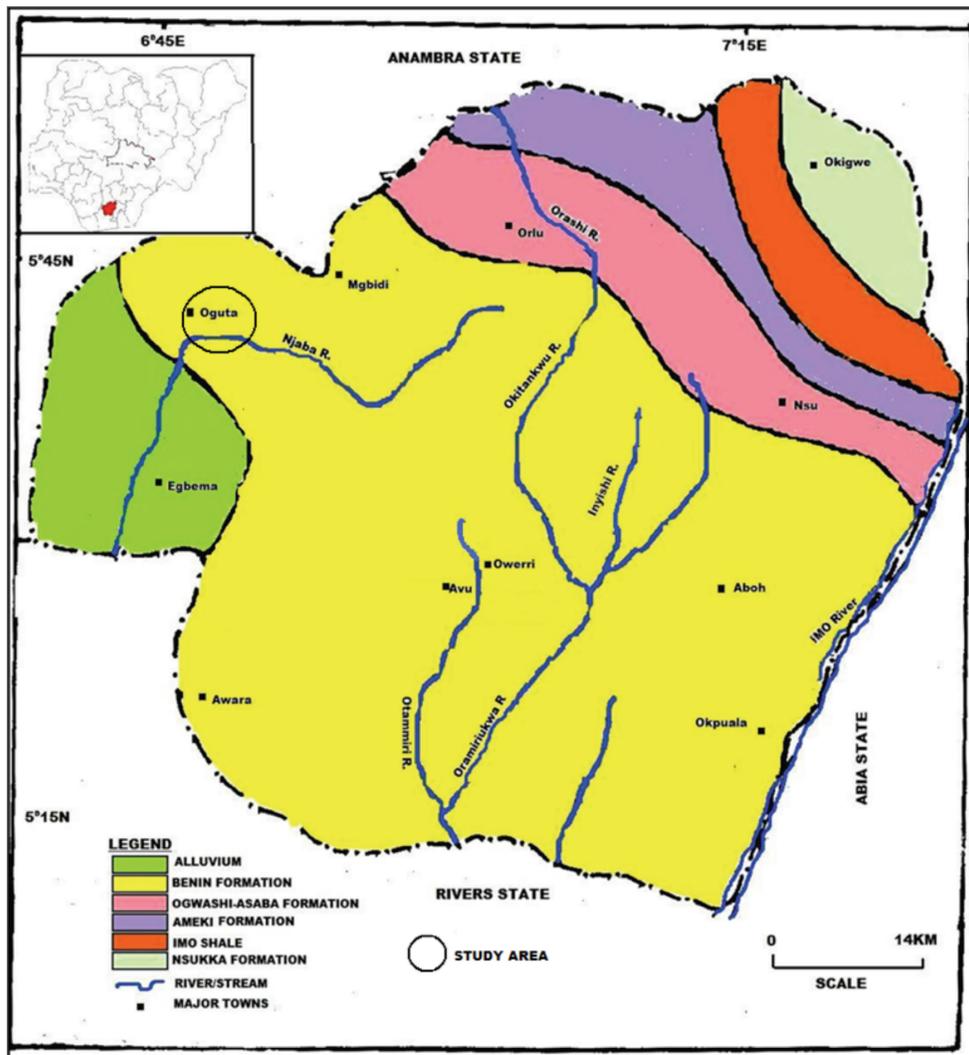


Figure 2. Monthly variations of gaseous emissions at the 'E' flow station

sition in the Eocene and continued to present day [8]. The local geological setting of Oguta Lake indicates that it falls within the Benin Formation which consists of friable sands, shale/clay lenses, isolated gravel patches, conglomerates and very coarse sandstones [9]. It is Pliocene to Miocene in age with a mean thickness of about 800m around the study area [10]. The surface geology of the Oguta area show a predominance of iron-rich sands that are occasionally pebbly and massively bedded [3].

Four rivers are associated with the Oguta Lake resource. Two of the rivers (Njaba and Awbana) flow into the lake, while the third one (Orashi) flows past its southwestern end (*Figure 1*). A fourth associated river (Utu) flows into the lake during the wet season only. About 87.6% of the total annual water inflow into the lake is from channel inflows from Njaba, Utu and Awbana rivers [4]. Other water inflow sources are groundwater and rainfall or precipitation. The lake is adequately recharged all the year round. In addition to these rivers, there is also some input from precipitation (rainfall).

4. Materials and Methods

Gaseous emissions at the 'E' flow station and Oguta Lake were measured using a Growcon digital gas

analyzer. The equipment which is calibrated in parts per million (ppm) has an accuracy of 0.01ppm. The emissions were measured on a bi-monthly basis starting in January, 2012 and ending in November, 2012. At Oguta Lake, the measurement of gaseous emissions was conducted at five gage stations designated S_1 to S_5 (*Figure 1*) and the mean bi-monthly values of the emissions were computed and recorded. The measurements of gaseous emissions at the 'E' flow station were conducted 10m away from the flare point. The flow station is located in Ezi- Orsu, about 9km away from Oguta Lake.

5. Results and Discussion

The concentrations of SO_2 at the 'E' flow station vary from 18 to 26ppm with a mean value of 16.67ppm, while NO_2 varies from 0.50 to 0.90ppm with a mean of 0.69ppm. The CO concentration varies from 10 to 16ppm with a mean of 12.33ppm while the NH_3 ranges from 2.0 to 3.60ppm with a mean of 2.97ppm. The concentrations of H_2S vary from 1.00 to 1.50ppm with a mean of 1.26ppm, while CH_4 concentrations vary from 3.50 to 5.0ppm with a mean of 4.02ppm (Table 1 and *Figure 3*). The mean concentrations (in percentage) of SO_2 , NO_2 ,

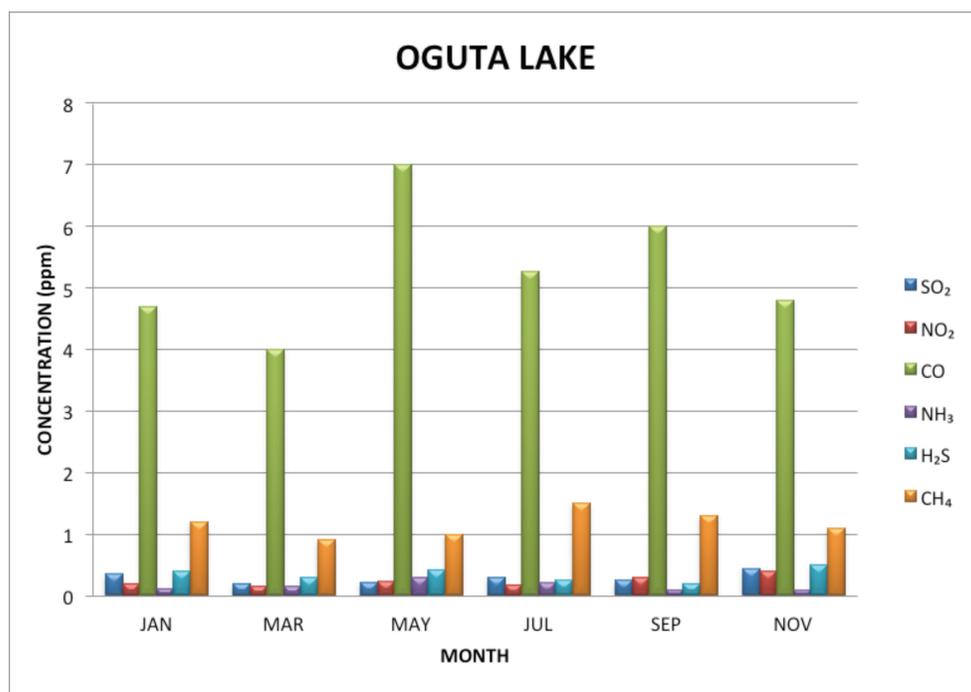


Figure 3. Monthly variations of gaseous emissions at Oguta Lake

CO, NH₃, H₂S and CH₄ are 43.9, 1.8, 32.4, 7.8, 3.3 and 10.6% respectively (Table 1 and Figure 4).

At Oguta Lake, the concentrations of SO₂ vary from 0.20 to 0.43ppm with a mean value of 0.29ppm, while NO₂ concentrations vary from 0.16 to 0.40ppm with a mean of 0.25ppm. CO concentrations vary from 4.00 to 7.00ppm with a mean of 5.29ppm while NH₃ range from 0.09 to 0.21ppm with a mean of 0.16ppm. The concen-

trations of H₂S vary from 0.20 to 0.50ppm with a mean of 0.35ppm, while CH₄ concentrations vary from 0.90 to 1.30ppm with a mean of 1.17ppm (Table 1 and Figure 5). The mean concentrations (in percentage) of SO₂, NO₂, CO, NH₃, H₂S and CH₄ are 3.9, 3.3, 70.4, 2.1, 4.7 and 15.6% respectively (Table 1 and Figure 6). A comparative illustration of the mean concentrations of gaseous emissions at the ‘E’ flow station is shown in Figure 6).

TABLE 1. Concentrations (ppm) of gaseous emissions at the ‘E’ flow station

Months	SO ₂	NO ₂	CO	NH ₃	H ₂ S	CH ₄
JAN	20	0.60	12	3.50	1.00	5.00
MAR	22	0.65	10	2.00	1.20	3.50
MAY	18	0.50	14	3.00	1.40	4.00
JUL	24	0.80	16	3.50	1.15	3.50
SEP	20	0.70	13	2.20	1.30	3.60
NOV	26	0.90	15	3.60	1.50	4.50
MEAN	16.67	0.69	12.33	2.97	1.26	4.02
MEAN, %	43.9	1.8	32.4	7.8	3.3	10.6
USEPA(2004)	0.145	0.155	<35.5			

Concentrations (ppm) of gaseous emissions at Oguta Lake

Months	SO ₂	NO ₂	CO	NH ₃	H ₂ S	CH ₄
JAN	0.35	0.20	4.70	0.12	0.40	1.20
MAR	0.20	0.16	4.00	0.16	0.30	0.90
MAY	0.22	0.23	7.00	0.30	0.42	1.00
JUL	0.30	0.18	5.26	0.21	0.25	1.50
	0.25	0.30	6.00	0.10	0.20	1.30
SEP						
NOV	0.43	0.40	4.80	0.09	0.50	1.10
MEAN	0.29	0.25	5.29	0.16	0.35	1.17
MEAN, %	3.9	3.3	70.4	2.1	4.7	15.6
USEPA(2004)	0.145	0.155	<35.5			

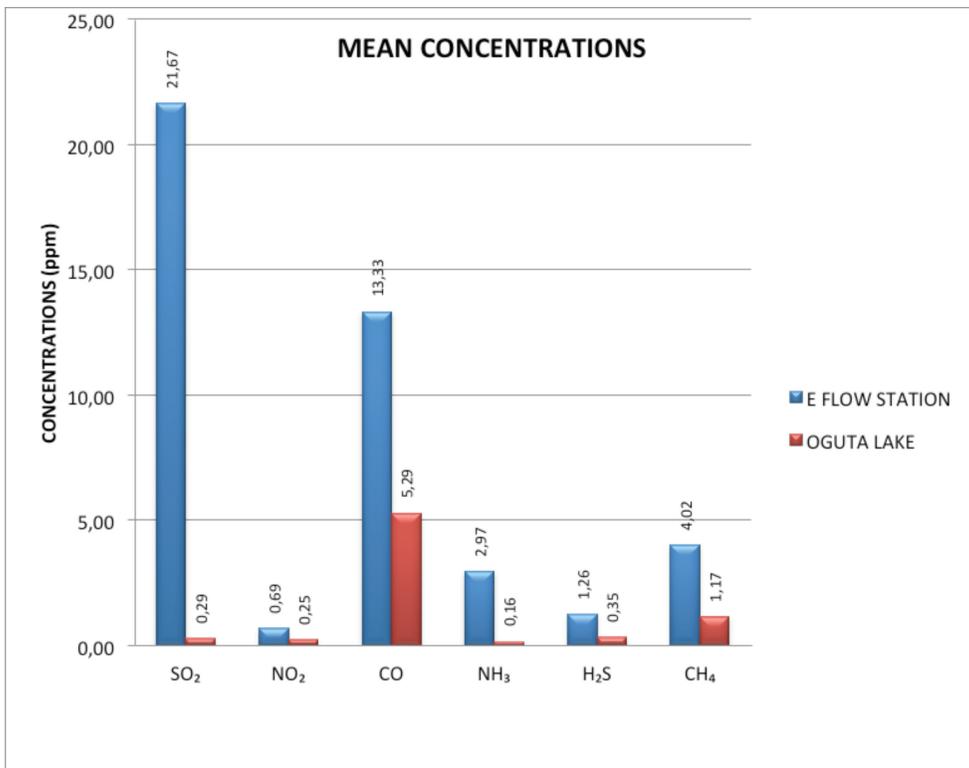


Figure 4. Mean concentrations of gaseous emissions at the 'E' flow station and Oguta Lake

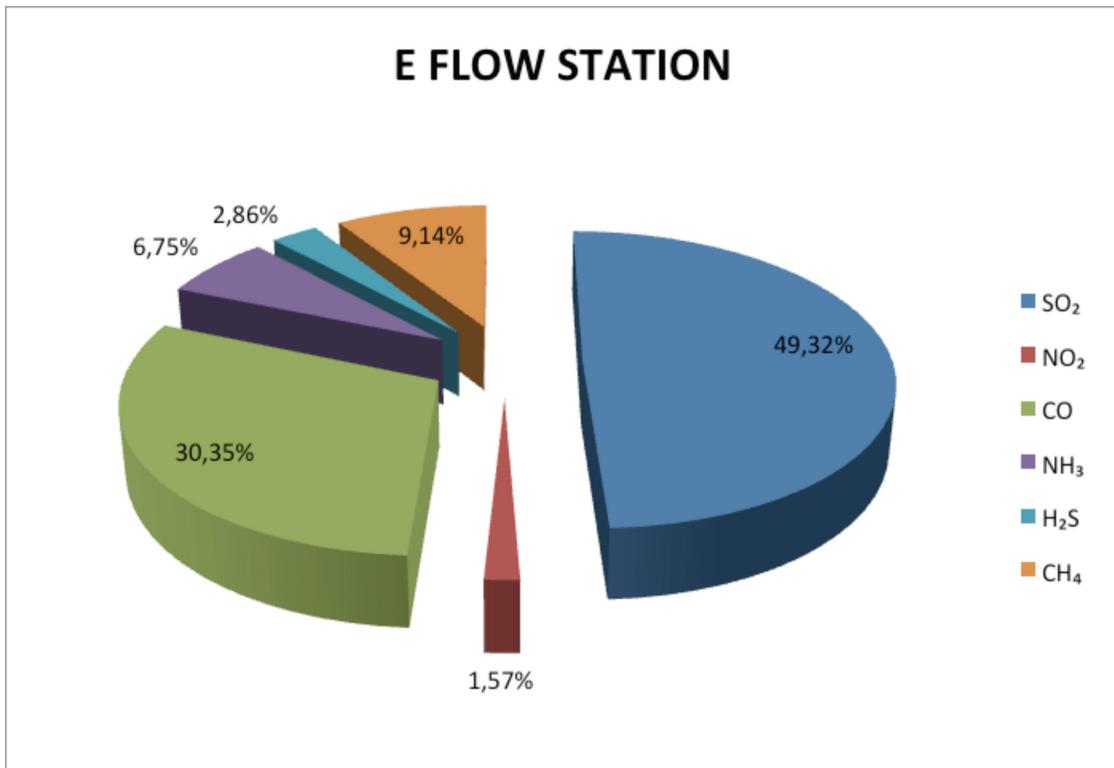


Figure 5. Pie-chart of ambient air quality at the 'E' flow station

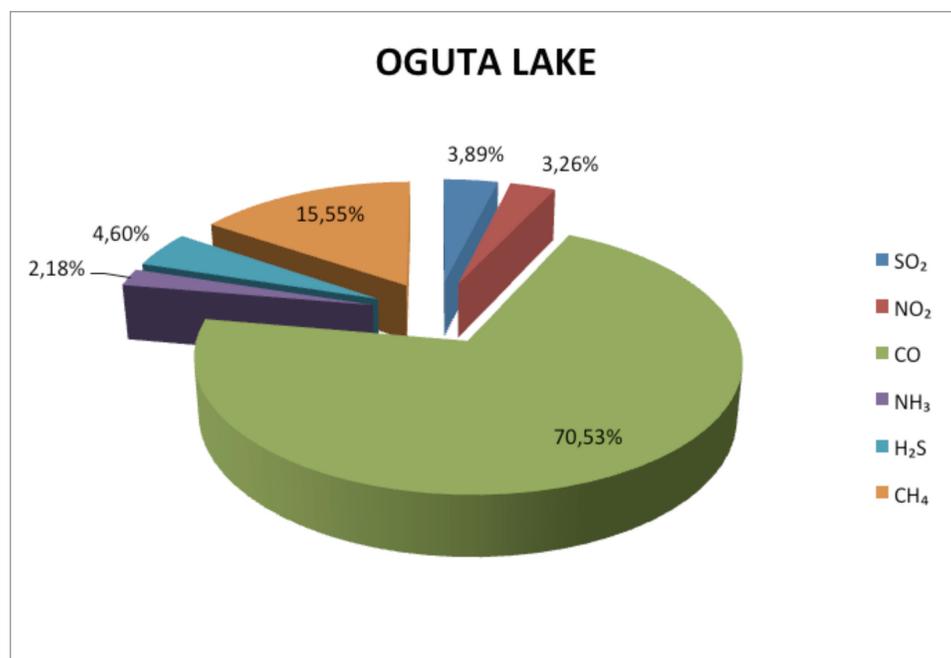
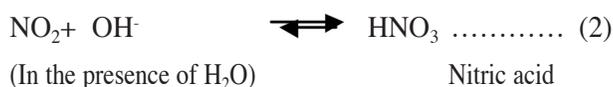
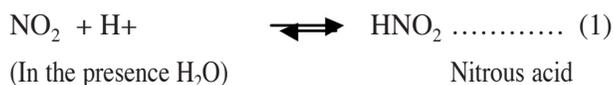


Figure 6. Pie-chart of ambient air quality at Oguta Lake

Field observations show that the main source of gaseous emissions within and around Oguta Lake and its watershed is the gas flaring at the ‘E’ flow station.

Apart from farming and fishing activities, the chemistry of the lake is constantly altered by the ambient air quality within and around it. The investigation reveals that the concentrations of SO₂ and NO₂ at the ‘E’ flow station flare site and Oguta do not meet the norms of safe air [1] and therefore constitute a threat to the environment. However, other measured gaseous emissions are within the norms of standard safe air [1]. In addition to the direct impacts of high SO₂ and NO₂ gas concentrations, such as respiratory illnesses, aggravation of asthma, cardiovascular difficulties, poor visibility and aesthetic damage, these gases contribute significantly to acid rain deposition. For instance, NO₂ reacts with water to form two strong acids (nitrous and nitric acids) thus contributing to acid rain formation (equations 1 and 2).



SO₂ also reacts with water to form two strong acids (Sulphur and Sulphuric acids), equations 3 and 4.



Acid rain carries multiple threats for the environment including damage to forests and destruction of aquatic life. Acid rain deposits lower the hydrogen ion (pH) concentrations of water resources. The high concentrations of SO₂ and NO₂ within and around Oguta Lake have resulted in lower pH levels in the Lake and even in its associated rivers. The mean pH of Oguta Lake obtained over one year of monitoring was 6.06 while those of the associated tributaries Utu, Awbana, Orashi and Njaba were 6.35, 6.30, 6.20 and 6.40 respectively [4]. Oguta Lake has in fact already been reported to be acidic 28 years ago [11]. The acidic nature of Oguta Lake is contrary to other surface water resources in Nigeria as most Nigerian fresh water resources are alkaline. For instance, the pH of Lake Chad is slightly alkaline [12] while that of Lake Kainji ranges from 6.3 to 8.4 [13]. The upper Ogun River has a pH range of 6.9 to 7.9 [14],

while the pH of the river Niger at Shagamu ranges from 7.09 to 7.96 [15].

Aquatic plants such as water hyacinth grow best within a pH of 7.0 to 9.20 [16] and therefore cannot thrive under a low pH. As the acidity level of surface water increases, submerged aquatic plants decrease, thus depriving aquatic fauna of their basic food source. At a pH of almost 6.0, freshwater shrimp cannot survive. At a pH of about 5.50, deep-dwelling decomposition bacteria begins to die, leaving behind un-decomposed leaf litter and other organic debris to collect in the hypolimnion (bottom water). This deprives planktons of their food and ultimately leads to their death.

As the accumulation of un-decomposed organic matter resulting from leave debris increases, toxic metals such as the aluminums, mercury and lead within this debris are released. These toxic metals are inimical to human health [16]. For instance, an excessive concentration of aluminum ($> 0.2\text{mg/l}$) in water potentially causes neurodegenerative disorders. Lead (when in excess of 0.01mg/l) causes cancer, interferes with the vitamin D metabolism, affects mental development in infants, and is toxic to the central and peripheral nervous systems. People who ingest mercury in contaminated

fish suffer serious health problems since mercury concentrations higher than 0.001mg/l affect kidneys and the central nervous system [16]. Below a pH value of about 4.50, all fish will die (Bourodemus, 1974). Acidic water attacks metals and destroys the paint of vehicles and civil structures (buildings and overhead bridges). The continuous gas flaring at the 'E' flow station at Ezi-Orsu has the potential of critically reducing the pH levels at Oguta Lake in the near future. This would result in the release of excessive concentrations of heavy metals (aluminum, lead, chromium, mercury and cadmium) into Oguta Lake and thus cause its pollution. In turn, this would have an adverse effect on the sustainable development of the Lake in terms of water supply and fisheries development. An appropriate pollution mitigation strategy is therefore urgently needed for Oguta Lake and even for its associated tributaries.

Apart from the direct impacts and drop in pH levels in Oguta Lake and associated river tributaries, gaseous emissions contribute significantly to global warming, which can increase the temperature of the Lake and, thus, speed up its thermal stratification. It is important to note that most thermally stratified lakes are eutrophic, and eutrophication is inimical to sustainable transport and tourism development.

Conclusion

The ambient air quality within and around Oguta Lake indicates excessive concentrations of SO_2 and NO_2 which has resulted in lower pH levels in the lake and its associated tributaries. A low pH level is capable of triggering the release of toxic metals such as lead, mercury, aluminum, chromium and cadmium into the Lake and its associated rivers. Apart from direct impacts such as respiratory illnesses, cardiovascular difficulties and aesthetic damage, gaseous emissions contribute to global warming, resulting in an increase in the temperature of the Lake and nearby water resources and speeding up their thermal stratification. Overall, ambient air quality is inimical to the sustainable development of the Lake and its associated tributaries in terms of water supply, tourism, transport and fisheries development.

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