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The Physical and Chemical Condition of Sombreiro River, Niger Delta, Nigeria

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Abstract: The physical and chemical condition of Sombreiro River in the Niger Delta area of Nigeria was studied for a period of two years (August, 2007-July, 2009). The mean temperature values varied from 28.02±1.03ºC (Odiemudie) to 28.31±0.96ºC (Ogbele). There was a steady trend of water temperature across the stations with a mean of 28.19± 0.77. The wet season mean water temperature ranged from 27.85 to 28.15ºC while the dry season ranged from 28.35 to 29.21ºC. The mean pH values varied from 6.33±0.31 (Ihuaba) to 6.50±0.26 (Ogbele). The pH of station 4 (Odiemudie) 6.50 is significantly different $p<0.01$. There was no significant difference between the pH of stations 2 and 3 at $p<0.01$. The pH values were stable across the stations and within sampling years. The mean pH for the study period across the stations was 6.40±0.25. The wet season pH ranged from 6.38-6.52 while the dry season pH ranged from 6.10-6.45. The mean salinity values ranged from 0.0‰ (Ihuaba and Odiemudie) to 7.67±2.63‰ (Degema) and values were significantly different ($p<0.01$) among the stations. The salinity trend was brackish at station 1 (Degema) and fresh stations 2-4. The mean value of the salinity across the stations was 1.96±0.96‰. The wet season salinity ranged from 0.11-6.66‰ while the dry season salinity ranged from 0.25-10.11‰. The mean DO values at the stations ranged from 6.84±0.08 mg/L (Degema) and 7.13±0.41 mg/L (Ogbele) with a mean of 7.0 mg/L. The DO value of station 2 (7.13±0.41 mg/L) was the highest and significant at $p<0.01$. This was followed by station 1 (Degema) 7.02±0.39 mg/L. Stations 3 and 4 had the same value of 6.96±0.23 mg/L. The wet season DO ranged from 6.94-7.14 mg/L while the dry season DO ranged from 6.60-7.13 mg/L. The mean BOD values ranged from 2.12±0.70 mg/L (Degema) and 2.46±0.54 mg/L (Ogbele). Station 1 (Degema) had the least value of 2.12±0.70 mg/L and is significantly different from stations 2, 3 and 4 at $p<0.01$). The mean BOD value across the stations was 2.37±0.44 mg/L. The wet season had a higher value of 2.43±0.01 mg/L while the dry seasons had a value 2.20±0.05 mg/L. The wet ranged from 2.02-2.61 mg/L while the dry season ranged from 2.11-2.35 mg/L. The mean conductivity values of the stations varied from 16.39±2.96 µS/cm (Odiemudie) to 18730.58±89.95 µS/cm (Degema) with the Degema value showing great significant difference at $p<0.01$). The conductivity values for stations 2, 3, and 4 showed no significant difference. The mean conductivity value across the stations was 4695.86±2885.24 µS/cm. The wet season had a mean of 4816.2±2945.23 µS/cm while the range was from 15.00-19215.4 µS/cm. For the dry season the values were from 19.61–17553.2 µS/cm.

Key words: Physical and chemical characteristics, Sombreiro River, Niger Delta, Nigeria

INTRODUCTION

Water is a simple chemical compound composed of two atoms of hydrogen and one atom of oxygen which bond covalently to form one molecule. It is known as the most complex of all the familiar substances that are single chemical compounds. It is an extraordinary substance which exists in the three states of matter (gaseous, liquid and solid states). In its pure state, water is colorless, odorless, insipid, freezes at 0ºC, has boiling point of 100ºC at a pressure of 760 mmHg, with a maximum density of 1 g/cm^3 at 4ºC. It is thermally stable at temperatures as high as 2700ºC. Water is neutral to litmus, with a pH of 7 and undergoes a very slight but important reversible self-ionization.

Water quality plays a role in the distribution of fish (Welcomme, 1979). The importance of measuring physical, chemical and biological variables was considered at the Technical Consultation on Enhancement of Fisheries of Small Water Bodies in Harare (Marshall and Moses, 1994). The Physico-chemical characteristics of water are important parameters as they may directly or

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indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Swingle, 1969; Moses, 1983).

Variability of water quality influences the toxicity levels of heavy metals on estuarine organisms as it affects the Physico-chemical composition of the ecosystem (Oyewo and Don Pedro, 2003). Water rising from market stalls and slaughter houses, streets washing and flushing of sewage which flow through drains into rivers altered the chemical composition of the water body thereby causing pollution (Ademoroti, 1996).

Temperature, turbidity light intensity, pH, dissolved ions such as NO_3 and PO_4 are reported to marshal the activities and composition of organisms (Collins, 1983; Ronald, 1988; Mukhtar *et al*., 1998). Organic waste dump caused environmental stress in coastal waters which resulted in the low landing of some important fisheries, (Wyatt and Yolarda, 1992; Appasany and Landquist, 1993; Lemly, 1996; Nweke, 2000). Size, structure and biomass of phytoplankton population and production are closely related to physico-chemical conditions of the water body (Mitchell-Innes and Pitcher, 1992).

Egborge (1988) reported that the coastal lagoons and tidal rivers of Nigeria have received relatively little hydrobiological attention. He concluded that most of the studies are of short duration and are based on few specific samples which are not significant in terms of baseline data necessary for future studies. Physical parameters in African running waters are influenced by rainfall and consequently by flood cycles (Egborge, 1972; Welcomme, 1979). Estuarine waters often have much higher residue level than inland waters (Ogan, 1988).

Much has been reported on the water quality of large lotic systems in Nigeria. Welcomme (1986) summarized data from different authors on the water quality of the Niger System. The parameters studied included pH, temperature, conductivity, and dissolved oxygen. He concluded that the state of knowledge on the hydrology of the Niger system was poor with a lot of gaps in the general ecological data of the river. In the Niger Delta the numerous oil fields and other developmental activities imply that monitoring of lotic water bodies can only be aided by records of Physico-chemical status and other resources.

Temperature is defined as the degree of hotness or coldness in the body of a living organism either in water or on land (Lucinda and Martin 1999; Kutty, 1987; Odum, 1971; Boyd, 1979). It is very important in waters because it determines the rate of metabolism of aquatic organisms. Temperature is measured insitu using any good mercury-filled Celsius thermometer or thermistor (APHA, 1995). Generally, the surface water temperature follows the ambient temperature and it is influenced by latitude, altitude, season, time of day, air circulation, cloud cover, substrate composition, turbidity, vegetation cover, water current and depth of the water body (Awachie, 1981; Ikusemiju, 1981; Leman, 1985; Umeham, 1989).

The growth, feeding, reproduction and migratory behavior of aquatic organisms including fish and shrimps are greatly influenced by the temperature of water (Lagler *et al*., 1977; Suski *et al*., 2006; Fey, 2006; Crillet and Quetin, 2006). Aquatic organisms have their own tolerance limits to temperature and this affects their distribution. Higher temperatures are recorded on the surface of river waters during midday and become low during the latter part of the night (Kutty, 1968). River water shows little thermal stratification because of the turbulent flow which ensures that any heat received is evenly distributed. Most tropical freshwaters have a stable temperature regime with seasonal variations between 20-30ºC (Adebisi, 1981). The temperature of natural inland waters in the tropics generally varies between 25-35ºC (Alabaster and Llyod, 1980; NEDECO, 1980, described the Niger Delta as humid/semi-hot equatorial area).

Temperature affects physical, chemical and biological processes in water bodies which alter the concentration of dissolved oxygen and rate of photosynthesis (Boyd, 1979). Under stress from increased temperature, shallow water ecosystems can undergo a state of change, characterized by the rapid loss of macrophytes and subsequent dominance of phytoplankton (Mckee *et al*., 2003). Water temperature can strongly affect the feeding patterns, growth rates and breeding seasons of fish and shell fishes. The lives of most aquatic organisms (especially poikilotherms) are controlled by water temperature. Aquatic organisms including fish may be classified ecologically in several ways according to environmental tolerance as stenothermal (lower or narrow) or eurythermal (higher or broad) respectively.

Along with light and nutrients temperature plays an important role in determining, phytoplankton productivity in aquatic ecosystems. Increased temperature increases metabolic activities which can lead to death. Temperature influences water quality and the distribution and abundance of aquatic organism, (Leman, 1985; Prasad, 2000). In water hydrogen ion concentration is measured in terms of pH, which is defined as the negative logarithm of hydrogen ion concentration (Boyd, 1979). This concentration is the pH of neutrality and is equal to 7. When the pH is higher than 7 it indicates increasing salinity and basicity while values lower than 7 tend towards acidity i.e. increase in hydrogen ion concentration. Pure water ionizes at 25ºC to give a concentration of 10 gL. Accurate measurement of pH may be taken insitu, using electronic glass electrode. However, APHA (1995) reported that pH measurements are affected by temperature in two ways; mechanical effects caused by changes in the properties of the electrode and chemical effects caused by equilibrium changes.

The pH higher than 7, but lower than 8.5 is ideal for biological productivity while pH lower than 4 is detrimental to aquatic life (Abowei, 2010). Most organisms including shrimps do not tolerate wide variations of pH over time and if such conditions persist death may occur. Therefore, waters with little change in

pH are generally more conducive to aquatic life. The pH of natural waters is greatly influenced by the concentration of Carbon (IV) oxide which is an acidic gas (Boyd, 1979). Phytoplankton and other aquatic vegetation remove carbon (IV) oxide from the water during photosynthesis, so the pH of a water body rises during the day and decreases at night (Boyd and Lichtkoppler, 1979). Rivers flowing through forests have been reported to contain humic acid, which is the result of the decomposition and oxidation of organic matter in them hence has low pH (Beadle, 1981). Abowei and George (2009) reported that the mean pH value of Okpoka Creek, Niger Delta ranged between 6.68 and 7.03 while the spatial and temporal variations were minimal. They also observed seasonal variation in pH between dry season (6.97) and wet season (6.81)

In the open ocean the pH of sea water falls within limits of 7.5-8.4 (Riley and Chester, 1971). Waters with low total alkalinity often have pH values between 6.5-7.5 before day break, but when phytoplankton growth is high, afternoon pH values may rise to 10 or even more (Swingle, 1961; Beasley, 1983). Changes in the acidity of water can be caused by acid rain, run-off from surrounding rocks and waste water discharges (Ibiebele *et al*., 1983). Waters with pH values of 6.5 to 9.0 are considered best for fish production, while the acid and alkaline death points are 4.0 and 11 respectively, (Swingle, 1969; Boyd, 1982). Low pH values or acidic waters are known to allow toxic elements and compounds such as heavy metals to become mobile thus producing conditions that are inimical to aquatic life (Gietema, 1992).

In the Niger Delta acidity level has also been observed as a major limiting factor influencing the distribution of mollusks. Nwadiaro (1987) investigated the longitudinal distribution of macro-invertebrates and fish in the lower Niger Delta (Sombreiro River) and reported that the distribution of mollusks was limited to the neutral slightly alkaline brackish water zone. The acidic nature of the New Calabar River was responsible for the lack of mollusks (Umeozor, 1995). Freshwaters of the Niger Delta tend to be acidic with pH range between 5.5-7.0 (Hamor and Philip-Howards, 1985; Adeniyi, 1986; Chinda, 2003).

Salinity is defined as the total concentration of electrically charged ions in water. These ions are the four major cations-calcium, magnesium, potassium and sodium and the four common anions-carbonates (CO_3), sulphates (SO_4), chlorides (Cl) and bicarbonates (HCO). Other components of salinity are charged nitrogenous compounds such as nitrates (NO_3), ammonium ions (NH_4) and phosphates (PO_4). It is expressed in units of ppm; S%0 or ppt or gram/L (UNESCO/WHO/UNDP, 1992). In general the salinity of surface waters depends on the drainage area, the nature of its rock, precipitation, human activity in the area and its proximity to marine water (McNeely *et al*., 1979).

Waters with salinity below 1‰ are fresh and waters with salinity higher than 1‰ are brackish/marine (Egborge, 1994b). Salinity is the major environmental factor restricting the distribution of marine and lacustrine taxa, resulting in the paucity of species in brackish water (Ramane and Schlieper, 1971). Decline in littoral fauna species richness from the river mouth inwards occurs on reduction in salinity resulting to the reduction of stenohaline species and decrease in species diversity from sandy to mud substances.

Salinity of surface water is relatively uniform as it is generally well mixed by waves, wind and tides. However, variation of surface water salinity due to the effects of rainfall, evaporation, precipitation and other weather related factors are often observed. Salinity is considerably higher during dry season when sea water penetrates far up the rivers, than in wet season when rain water and flood from the Niger and Benue rivers drive the salt water back towards the sea. The Bonny River has high saline penetration from the Atlantic Ocean, which salinity fluctuates with the season and tide. Salinity is a major driving factor that affects the density and growth of aquatic organism's population in the mangrove swamp (Powell *et al*., 2001; Wuenschel *et al*., 2001; Ansa, 2005; Jamabo, 2008).

The amount of dissolved oxygen in water is very important for aquatic organisms. Dissolved oxygen affects the growth, survival, distribution, behavior and physiology of shrimps and other aquatic organisms (Solis, 1988). Oxygen distribution also strongly affects the solubility of inorganic nutrients since it helps to change the redox potential of the medium. It can also determine whether the environment is aerobic or anaerobic (Beadle, 1981).

The principal source of oxygen that is dissolved in water is by direct absorption at the air-water interface which is greatly influenced by temperature (Plimmer, 1978; Kutty, 1987). At low temperature more oxygen diffuses into the water. The solubility of oxygen in water is controlled by some major factors such as temperature, salinity, pressure and turbulence in the water caused by wind, current and waves. Surface agitation of water helps to increase the solubility of dissolved oxygen in water (Boyd, 1982). In rivers and streams the turbulence ensures that oxygen is uniformly distributed across the water and in very shallow streams the water may be supper saturated (Abowei *et al*., 2010).

Oxygen concentration in water is controlled by four factors: photosynthesis, respiration, exchanges at the air-water interface, and supply of water to the water body or pond (Krom *et al*., 1989; Erez *et al*., 1990). A major part of dissolved oxygen is observed to come from photosynthesis processes and only a small part originates

from the atmosphere (Milstein *et al*., 1989). Boyd and Lichtkoppler (1979) reported that there is significant fluctuation in dissolved oxygen concentration during a 24 h period in waters of lakes and ponds. Dissolved oxygen is usually lowest in the early morning just after sunrise, increasing during daylight hour to a maximum in late afternoon and decreasing again at night. The magnitude of fluctuation is greatest in waters with high plankton bloom and least with those having low plankton abundance. Production of oxygen in cloudy day is less than on a clear or partly cloudy day (Swingle, 1968). Dissolved oxygen concentration of 5.0 mg/L and above are desirable for fish survival (Boyd and Lichtokoppler, 1979).

Low dissolved oxygen concentrations are known to be one of the major problems to faunal and floral survival in the aquatic environment. This has been reported by Erkk *et al*. (1996) in their study of the Black and Baltic Sea. Low concentration of dissolved oxygen created anoxic condition within the Black and Baltic Sea (Saiz-Salinas, 1997). The problems of anoxia are the major causes of faunal depletion in aquatic ecosystems.

The amount of oxygen needed to completely decompose the organic matter present in the water to simplest molecules, carbon (iv) oxide and water is known as the Biochemical Oxygen Demand (BOD) of the water. The greater the BOD the higher the degree of pollution. When the organic loading of the aquatic environment becomes abnormally high, the BOD far exceeds the available oxygen. Biochemical oxygen demand is used as a measure of the quantity of oxygen required for oxidation of biodegradable organic matter present in a water sample by aerobic and anaerobic biochemical action.

Biochemical Oxygen Demand (BOD) is thus one of the measures of organic loads in an aquatic system as well as an indicator of levels of organic pollution (Odukuma and Okpokwasili, 1990; Bagariano, 1992). However, low BOD levels water support high organic enrichment. Clerk (1986) reported that BOD range of $\geq 2 \leq 4$ does not show pollution while levels beyond 5 mg/L is indicative of serious pollution. Water bodies with BOD levels between 1.0 and 2.0 mg/L were considered clean; 3.0 mg/L fairly clean; 5.0 mg/L doubtful and 10.0 mg/L definitely bad and polluted (Moore and Moore, 1976; Chinda *et al*., 1991).

Conductivity is a measure of the ability of water to conduct an electrical current. The conductivity of water is dependent on its ionic concentration and temperature. Distilled water has a conductivity of about 1μmbos/cm and natural waters have conductivity of 20-1500 μmbos/cm (Abowei *et al*., 2010). Conductivity provides good indication of the changes in water composition particularly its mineral concentration.

Variations of dissolved solids in water could affect the relative quantities of the various components. There is a relationship between conductivity and total dissolved solids in water. As more dissolved solids are added, water's conductivity increases (Abowei *et al*., 2010). Conductivity of salt water is usually higher than that of freshwater because the former contains more electrically charged ions than the latter. The freshwater zone of the rivers of the Niger Delta can thus be said to be low in ions. The total load of salts of water is in direct relation with its conductivity (Golteman and Kouwe, 1980; Delince, 1992). Conductivity is an index of the total ionic content of water, and therefore indicates freshness or otherwise of the water (Egborge, 1994a; Ogbeibu and Victor, 1995).

Conductivity of freshwater varies between 50 to 1500 hs/cm (Boyd, 1979), but some polluted waters reach 10,000 hs/cm. Seawater has conductivity around 35,000 hs/cm and above. The major constituents of the dissolved substances in water are calcium ion (Ca^{2+}), Magnesium (Mg^{2+}), hydrogen trioxcarbonate (iv) (HCO_3), trioxocarbonate (iv) (CO_3), trioxonitrate (v) (NO_3) and tetraoxophosphate (vi) (PO_4). They are the necessary constituents of aquatic animals which partly come from their food (Beadle, 1981). Verheust (1997) stated that conductivity can be used as indicator of primary production (chemical richness) and thus fish production. Sikoki and Veen (2004) observed a conductivity range of 3.8-10 hs/cm in Shiroro Lake (Imo State) which was described as extremely poor in chemicals. They were of the view that fishes differ in their ability to maintain osmotic pressure, therefore the optimum conductivity for fish production differ from one species to another. This article will provide data on some physical and chemical condition of Sombreiro River in the Niger Delta area Nigeria to compliments existing data, provides baseline information for management decisions in the management of the fishery and similar water bodies.

MATERIALS AND METHODS

Study area: The study was carried out for a period of two years (August, 2007-July, 2009) in Sombreiro River, in the Niger Delta of Nigeria. It is one of the rivers that drains the western part of Rivers State. The river provides nursery and breeding grounds for a large variety of fish species (Ezekiel *et al*., 2002). Four sampling stations were established along the length of the Sombreiro River whenever, it was accessible by road. Sombreiro River is located in three local government areas of Rivers stale-Ogba/Egbema/Ndoni and Degema between Latitude 6º30′ and 70ºE and Longitude 4º12′ and 6º17′ N. It is a distributary of the River Niger which arises from northern boundary of Rivers State with Imo State. it is one of the series of the Niger Delta rivers which drain into the Atlantic Ocean and is connected to other rivers via creeks in the coastal area of the Niger Delta (Ezekiel, 1986, 2001) .

The river is narrow and steep as it flows southwards, it widens and the steep sidedness gradually disappears starting from the middle reaches. The system is lotic throughout the year; the lotic period reaches its peak in January to February (dry season) when the water level has fallen to the maximum. In August-September (wet season), the lotic nature of the river is reduced due to flooding (Ezekiel, 1986). The river is contained within the tropical rainforest although the lower reach is within the brackish mangrove zone.

From upstream the river bed consists of stones and gravels, the middle zone tending to be sandy with the sand bed giving way to a muddy one at the lower reach of the river (Ezekiel, 1986). A part from areas of human disturbance, the river is fringed by riverside forest. Numerous human activities such as fishing, sand nuning, dredging, mangrove cutting, logging of timber and transportation. These may be potential sources of pollution to the environment. Public toilets were observed at each of the sampling stations. Also observed were refuse dumps and run-offs into the river from the rivernie communities. The wastes from the comities may constitute source of pollution to the river.

Four sampling stations were established along the length of Sombreiro River. Stations were chosen in such a manner to provide for even spread for effective sampling. Each of the stations was visited once a month, usually between the 15th and 22nd. Photographs were taken of each station to illustrate the habitat. Only qualitative descriptions of stations were made in order to classify the stations according to general habitat types. The four stations investigated in this study are described below on the basis of personal visual observations.

Station 1 (Degema): This is the largest of all the sampling stations. The vegetation fringing the river at the left and right banks consists of mangrove plants such as *Rhizophora*, *Avicennia* and *Nypha Fruticans* (Nypa palm), arising from a characteristic muddy substrate that produces a foul odour. The water is highly turbid in the rainy months and clear in the dry months. This station is a brackish and tidal environment. There is no observable unidirectional flow of the water at this station due to the very wide nature of the river; thus the surface current is not very distinct to be determined. The bed of the river at this station is a mosaic mud and sand. No farmland was observed at this station but there were public toilets which discharge human astes directly into the river.

Station 2 (Ogbele): At station 2, mangrove vegetation is replaced by riverine forest consisting mainly of *Raphia*, *Pandanus*, *Sanderiana*, *Calamas* sp. (swamp cane), *Khaya* sp. (Mahogany), *Vapaca* sp, *Ficus Vogeliana* and *Triculia. african.* Aquatic marcophytes include *Nymphace* sp., *Eichornia crassipes*, *Sagittana* sp., *Pistia stratictes*. The station was flooded in the rainy season when the current velocity is slow. The station has a little tidal influence from the immediate tidal mangrove zone. The bed of the river at this station consists of sand and small gravel. No farmland was noticed but there were public toilets which discharge human wastes directly into the river.

Station 3 (Ihuaba): The vegetation fringing the river at this station is a mixture of riverine and terrestrial vegetation although no farmland was seen. The common plants noticed here are the *Raphia* and *Elaeis guineensis* (palm trees). The aquatic macrophytes include *Typha lotifolia* (cat tail) and *Potamogetom* sp. (pond weed). The station was flooded from August to October with the flood receding from November to February. The speed of the current is slow in the rainy season. The bottom of the river at this station consists of sand and gravel of various sizes. No farmland was observed but there were public toilets which discharge human waste into the river.

Station 4 (Odiemudie): The vegetation consists of a terrestrial vegetation in which can be seen farmland, and riverine vegetation extending into a large area of swamps. Some include *Raphia*, *Pandanus Sanderiana Elaeis guineensis* (palm trees) Aquatic macrophytes include/ Pomea aquatica, Lemna sp. (duck weed), *Utricularia* sp., *Nympaea* sp. and *Pistia stratiotes* (water lettuce). Current is moderate in the rainy months, becoming fast in the dry months when the flood recedes. The water is clear and the bottom consists of small stones, gravel of various sizes and sand.

Sample collection: Water samples for Physico-chemical analysis were collected at subsurface from the entire sampling stations one every sampling day. Fortnightly, routine sampling was conducted between 8.00 and 12.00 h on each sampling day. The sampling containers used are: 250 mL reagent bottles and 1500 mL plastic containers. A day before the sampling day, the containers were washed, dried and corked, fully labeled and stored under laboratory conditions to avoid contamination. Subsurface water samples were collected at a depth of about 10-20 cm. The dark colored 250 mL glass bottles were used for the Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) analysis while the 1500 mL (1.5 L) plastic containers were used to collect water for the general purpose analysis. Usually, sampling bottles and containers were rinsed three times with the river water at water at each sampling station before the collection of samples. Water samples were collected by lowering the sampling bottled or containers by hand to a depth of about 20 cm below the surface level. Each sample container was treated according to analysis to be carried out on them in the field before they were transported to the laboratory for analysis.

The physico-chemical parameters of Sombreiro River water investigated were water temperature, hydrogen ion concentration (pH), salinity, Dissolved Oxygen (DO),

Biochemical Oxygen Demand (BOD) and electrical conductivity. The methods used were described by Golteman *et al*. (1978) and Clesceri *et al*. (1998). The water temperature was measured in the field using simple mercury in glass thermometer (0-110ºC) graduated at 0.1ºC intervals. Thermometer was lowered directly into the water and when the mercury stabilizes at a point, the temperature values were read. Two readings were taken and the mean of the two readings was calculated and recorded as the subsurface water temperature for that station. This was repeated for all the four stations.

The water hydrogen ion concentration (pH) was determined in situ using a standardized HACH portable electronic pH meter model ECIO. The readings were taking by lowering the probe of the pH meter into the water sample and the valve read-off from the meter. The mean of two such readings was calculated and recorded as the pH of the water at that particular station. This was carried out for all the stations throughout the sampling period.

The salinity of the water samples of each of the four stations was measured in the laboratory using multi-water measuring meter- Horiba water checker model U-10 micons. For each station, small quantity of water sufficient to make proper contact with the electrode (prope) of the meter, was poured into a beaker. The reading was taken by lowering the probe of the meter into the beaker containing the water sample and left for about three minutes for the meter to standardize and then the reading taken in S = ‰.

The Dissolved Oxygen (DO) contents of the water samples from the four sampling station measures in mg/L were determined in the laboratory using the iodometric (Wrinkler's) method (Clesceri *et al*., 1998). The water samples collected in the dark coloured 250 mL BOD bottles were fixed in the field by adding 1.0 mL of Winkler's solution 1 (Mangaese (ii) tetraoxosulphate (vi) Monohyrate - $MnS0_4H_20$) and 1.0 mL of Winkler's solution II (Sodium Hydroxide and sodium iodide) using a 2.0 mL pipette. To dissolve the precipitate of Manganese II hydroxide farmed, 1.0 mL of concentrated tetraoxosulphate (vi) acid H_2SO_4 was added below the solution inside the reagent bottle using the pipette.

In the laboratory, 20.0 mL of the fixed water samples from each of the four stations were respectively pipetted into 250 mL flat bottom conical flasks and 0.0125 m standardized disodium trioxosulphate (iv) ($Na_2S_2O_3$) solution was titrated against each, using 2.0 mL of 1.0% starch solution as indicator. The point at which the blue color first disappeared indicated the end point of each titration. The titration was repeated thrice for each station and the average titre was determined. From the average titre values obtained for each station, the dissolved oxygen concentration was calculated in mg/L using the formular:

$$02\ \text{mg/L} = \frac{t \times 101.6}{20\ \text{mL of water sample}}$$ Clesceri *et al*. (1998)

where t = titre or volume of thiosulphate used.
101.6 = constant.

The Biochemical Oxygen Demand (BOD) was calculated using the 5-day BOD test adapted from Clesceri *et al*. (1998). This analysis uses the same principle and procedure for the dissolved oxygen determination. The difference was that the water samples collected from the various sampling stations for the BOD under the same condition as DO analysis was tightly stoppered and incubated in the dark for five days before analysis. The calculated BOD_5 were recorded as the difference between the initial dissolved oxygen value measured in the field and the value of dissolved oxygen determined after five days of incubation. The results were recorded as BOD mg/L of water sample for each station.

The electrical conductivity of the water from the four sampling stations was determined insitu using a model cm-21 lovibond conductivity meter. Some water samples from each station were poured into four different 200 mL beakers representing each station. The readings were taken from each of the beakers containing the water sample by lowering the probe of the meter into the beakers and allowing it for two minutes for the meter to standardize and the readings taken in µs/cm and recorded.

RESULTS

The variation of physical and chemical parameters in sampling station and season is presented in Table 1 and 2, respectively. The mean temperature values varied from 28.02±1.03ºC (Odiemudie) to 28.31±0.96ºC (Ogbele) and are not significantly different ($p<0.01$) among stations. There was a steady trend of water temperature across the stations with a mean of 28.19±0.77. There was slight seasonal variation of temperature between wet (27.98±0.80) and dry season (28.70±0.50). The wet season mean water temperature ranged from 27.85ºC to 28.15ºC while the dry season ranged from 28.35 to 29.21ºC.

The mean pH values of Sombreiro River varied from 6.33±0.31 (Ihuaba) to 6.50±0.26 (Ogbele). The pH of station 4 (Odiemudie) 6.50 is significantly different $p<0.01$. There was no significant difference between the pH of stations 2 and 3 at $p<0.01$. The pH values were stable across the stations and within sampling years. The mean pH for the study period across the stations was 6.40±0.25. There was seasonal variation in pH between wet 6.46±0.08 and dry season (6.26±0.28). The wet season pH ranged from 6.38-6.52 while the dry season pH ranged from 6.10-6.45.

Table 1: Summary of Analysis of Variance (Anova) for Inter-Station Physico-chemical Parameters of Sombreiro River, Niger Delta Nigeria (August 2007-July 2009)

	Sampling stations				
	1	2	3	4	
Parameters	Degema	Ogbele	Ihuaba	Odiemudie	Mean
Temp(ºC)	28.21±0.98[a]	28.31±0.96[a]	28.21±0.95[a]	28.02±1.03[a]	28.19±0.77
Ph	6.42±0.30[ab]	6.35±0.34[b]	6.33±0.31[b]	6.50±0.26[a]	6.40±0.25
Salinity (‰)	7.67±2.63[a]	0.15±0.08[b]	0.00±0.00[b]	0.00±0.00[b]	1.96±0.96
Do mg/L	6.84±0.08[c]	7.13±0.41[a]	7.02±0.39[b]	7.02±0.36[b]	7.00±0.38
BOD mg/L	2.12±0.70[b]	2.46±0.54[a]	2.44±0.47[a]	2.44±0.37[a]	2.37±0.44
Conductivity µS/cm	18730.58±89.95[a]	18.03±2.97[b]	18.43±3.02[b]	16.39±2.96[b]	4695.86±2885.24

a, b, c: Means within columns with the same superscript are not significantly different at p<0.01

Table 2: Seasonal Variation of Mean Values, Standard Deviation and Range of Physico-chemical Parameters of Sombreiro River, Niger Delta, Nigeria (August 2007-July 2009)

	Wet Season		Dry Season	
Parameter	range	Mean	range	Mean
Temp(ºC)	27.85-28.15	27.98-0.80[b]	28.35-29.21	28.70±0.50[a]
pH	6.38-6.52	6.46±0.08[a]	6.10-6.45	6.26±0.28[b]
Salinity (‰)	0.11-6.66	1.69±0.83[b]	0.25-10.11	2.59±0.76[a]
DO mg/L	6.94-7.14	7.02±0.13[a]	6.60-7.13	6.96±0.23[a]
BOD mg/L	2.02-2.61	2.43±0.01[a]	2.11-2.35	2.20±0.05[b]
Cond µS/cm	15.00-19215.4	4816.2±2945.23[a]	19.61-17553.3	4403.5±2784.35[a]

Mean with the superscript are not significantly different at p<0.01

The mean salinity values of Sombreiro River varied from 0.0‰ (Ihuaba and Odiemudie) to 7.67±2.63‰ (Degema) and values were significantly different (p<0.01) among the stations. The salinity trend was brackish at station 1 (Degema) and fresh stations 2-4. The mean value of the salinity across the stations was 1.96±0.96‰. Some seasonal variation was observed with lower salinity during the wet season (1.69±0.83‰) than the dry season (2.59±0.76‰). The wet season salinity ranged from 0.11-6.66‰ while the dry season salinity ranged from 0.25-10.11‰.

The mean DO values at the stations of Sombreiro River varied from 6.84±0.08 mg/L (Degema) and 7.13±0.41 mg/L (Ogbele) with a mean of 7.0 mg/L. The DO value of station 2 (7.13±0.41 mg/L) was the highest and significant at p<0.01. This was followed by station 1 (Degema) 7.02±0.39 mg/L. Stations 3 and 4 had the same value of 6.96±0.23 mg/L. The wet season DO ranged from 6.94-7.14 mg/L while the dry season DO ranged from 6.60-7.13 mg/L. No seasonal variations was observed at p<0.01.

The mean BOD values ranged from 2.12 ± 0.70 mg/L (Degema) and 2.46±0.54 mg/L (Ogbele). Station 1 (Degema) had the least value of 2.12±0.70 mg/L and is significantly different from stations 2, 3 and 4 at p<0.01). The mean BOD value across the stations was 2.37±0.44 mg/L. There was seasonal variation between the wet season and dry season. The wet season had a higher value of 2.43±0.01 mg/L while the dry seasons had a value 2.20±0.05 mg/L. The wet ranged from 2.02 – 2.61 mg/L while the dry season ranged from 2.11-2.35 mg/L.

The mean conductivity values of the stations varied from 16.39±2.96 µS/cm (Odiemudie) to 18730.58±89.95 µS/cm (Degema) with the Degema value showing great significant difference at p<0.01). The conductivity values for stations 2, 3, and 4 showed no significant difference. The mean conductivity value across the stations was 4695.86±2885.24 µS/cm. No seasonal variation was observed between the wet and dry seasons. The wet season had a mean of 4816.2±2945.23 µS/cm while the range was from 15.00-19215.4 µS/cm. For the dry season the values were from 19.61-17553.2 µS/cm.

DISCUSSION

The temperature values recorded in Sombreiro River are considered normal since it is located in the Niger Delta which is described by NEDECO (1980) as humid/semi-hot equatorial area. The observed temperature regime in this study is in agreement with the reports of Adebisi, 1981 who stated that most tropical freshwaters have a stable temperature regime with seasonal variations between 20-3ºC and Alabaster and Lloyd (1980) who also stated that the temperature of natural inland waters in the tropics generally ranged from 25-35ºC. The temperature values obtained in this study compare favorably with those reported by earlier workers in the Niger Delta waters. These include Hart and Zabbey (2005) (27.3-28.7ºC), Edogbolu and Aleleye-Wokoma (2007) (26-31ºC), Abowei and George (2009) (27-31ºC) and Deekae *et al*. (2010) (25.05-32.20ºC). Furthermore, it compares favorably with Lagos Lagoon waters reported by Emmanuel and Onyema (2007) (23.5-30.8ºC) and Nkwoji *et al*. (2010) (29-29.5ºC).

The minimum temperature was recorded in July during the wet season. This agrees with the work of Abowei and George (2009) who also recorded minimum temperature in July. Spatial differences in temperature

was not significantly different ($p<0.01$). This may be attributed to the thick vegetation cover along the banks of the river and the earlier reported work of Edokpayi and Nkwoji (2007) that temperature is not a major factor in tropical aquatic systems. The non-spatial variation observed in this study is also in agreement with the report of Abowei and George (2009) who stated that temperature remained steady in the stations of Okpoka Creek in the Niger Delta. This finding is also similar to the report of Ogamba *et al*. (2004) who attributed minimal variation in temperature between stations to the absence of micro climatic variations in temperature.

Mean temperature showed significant seasonal variation between wet and dry season ($p<0.01$). The mean temperature is significantly higher in the dry season than the wet season. A similar trend was observed by Ekeh and Sikoki (2003) and Abowei and George (2009). The mean higher temperature value of the dry season is normal since heat from sunlight increases surface water temperature. Similarly, the fall in wet season is attributable to rainfall. This finding agrees with the report of Welcomme (1979) that physical parameters in African running waters are influenced by rainfall and flood cycles.

pH of Sombreiro ranged from 6.33±0.34 - 6.50±0.26 with mean value of 6.40±0.25 at the stations. The pH values obtained in this study compares favorably with the observation of Hamor and Philip-Howard (1985), Adeniyi (1986) and Chinda (2003) that fresh waters of the Niger Delta tend to be acidic with pH range of 5.5-7.0. The mean pH value of 6.40 recorded in this study is also similar to the reports of other authors on Niger Delta water bodies by Nwadiaro *et al*. (1982), Chinda and Pudo (1991), Akpan and Offenn (1993), Hart and Zabbey (2005), Edogbolu and Aleleye Wokoma (2007) and Deekae *et al*. (2010). The observed acidic pH in this study agrees with the report of Abowei (2010) that waters with little change in pH are generally more conducive to aquatic life. Furthermore, the recorded low pH values in this study also agrees with the observation of Beadle (1981) that rivers flowing through forests contain humid acid which is the result of decomposition and oxidation of organic matter and hence low pH.

The pH of station 4 (6.50) is significantly different $p<0.01$). The pH of station 1 (6.42) slightly varies from station 2 (6.35) and station 3 (6.33) that were not statistically different $p<0.01$. These differences were attributed to sundry effluents discharged during the down and course of the river (Abowei and George, 2009)

The mean pH of Sombreiro River shows significant seasonal variations between wet season and dry season. The wet (6.46±0.08) and dry (6.26±0.28). Seasons were significantly different $p<0.01$. Variations in pH in some inland rivers in Nigeria have also been reported by RPI (1985), Opute (1990), Egborge (1994a), Ajayi and Osibanjo (1981), Adebisi (1981), Moses (1988), Akpan and Offem (1993), Allison (2006), Abowei and George (2009), Deekae *et al*. (2010) and Nkwoji *et al*. (2010).

The Salinity of Sombreiro River especially at Station 1 was between 0.00 - 7.67±2.63% which is a clear indication of fresh water habitat in the upper and middle courses of the river and brackish habitat in the lower course of the river. In this study, station 1 is typically brackish while station 2-4, are typically fresh water environments. This agrees with the report of Egborge (1994a) that waters with salinity below 1‰ are fresh and waters with salinity higher than 1‰ are brackish/marine. The mean salinity recorded in the stations of Sombreiro river stations is 1.96‰ and is significantly different $p<0.01$ across the stations. The highest monthly mean salinity occurred in March (3.1‰) while the lowest monthly mean salinity occurred in July (1.2‰) during the dry and wet seasons respectively. These mean salinity values compare favorably with those reported by Hart and Zabbey (2005), Emmanuel and Onyema (2007), Abowei and George (2009), Deekae *et al*. (2010) and Nkwoji *et al*. (2010).

Seasonal variation was observed in the salinity of Sombreiro river. The mean wet season value 1.69‰ and mean dry season value 2.59% were significantly different $p<0.01$. Variations in the physical and chemical quality of water in the Niger Delta have been reported by RPI (1985), Chinda and Braid (2003) and Ogamba *et al*. (2004). The combined effect of high humic acid freshwater ion inputs are attributed to the variations (Ogamba *et al*., 2004). The variation in salinity may also be attributed to drainage area, the nature of its rocks precipitation, human activity in the area and proximity to marine water (McNeely *et al*., 1979)

The profound differences observed in the seasonal variation of salinity in Sombreiro River have also been reported from other water bodies in Nigeria (Onyema and Nwankwo, 2009; Nkwoji *et al*., 2010; Deekae *et al*., 2010; Hart and Zabbey, 200; Emmanuel and Onyema, 2007).

The quantity of mean dissolved oxygen in Sombreiro River water ranged from 6.84-7.13 mg/L with a mean value of 7.0 mg/L. This mean value agrees with the report of Boyd and Lichtokoppler (1979) that dissolved oxygen concentration of 5.0 mg/L and above are desirable for fish survival. The obtained result also compares favorably with the finding of Biney, (1990) that fresh and brackish waters have mean dissolved oxygen concentrations with a range of 6-8 mg/L. The dissolved oxygen of station 2 (Ogbele) is 7.13 and is significant at $p<0.01$. This may be due to the fact that station 2 is a freshwater tidal environment and also affected by natural lotic movement of the water.

The lowest dissolved oxygen concentration occurred in Kurle Lagoon which is regarded as grossly polluted

(Biney, 1990). Both fresh and coastal waters had mean dissolved oxygen concentrations with a range of 6-8 mg/L (Biney, 1990). He reported that differences in dissolved oxygen concentrations between coastal and freshwater ecosystems had more to do with whether the environments were riverine or lacustrine and the type of discharges a particular water body receives. Nwadiaro *et al*. (1982) in their studies of drinking water quality of some rivers in the Niger Delta reported a mean dissolved oxygen value of 7.29 mg/L. In the Cross River System, Moses (1979) recorded dissolved oxygen values ranging from 2.8 to 4.5 mg/L with the lowest values at Eban Station.

Onyema and Nwankwo (2009) and Nkwoji *et al*. (2010) have reported higher wet season values of DO. This was attributed to flood water dilution and reduced resident time of polluted waters. Polluted water with untreated sewage, sawdust, petrochemical materials, detergent and industrial effluents has been reported to have low DO values. Emmanuel and Onyema (2007) reported dissolved oxygen range of 3.4-4.5 mg/L. Nkwoji *et al*. (2010) reported highest DO value of 5.2 mg/L from the stations of Lagos Lagoon. UNESCO/WHO/UNDP (1984) recommended 5 mg1^{-}1 for water quality assessment. Ogamba *et al*. (2004) reported lower wet season DO values compared to dry season values in Elechi Creek. This was attributed to flood and municipal drains depositing wastes (organic, inorganic and debris) into the estuary leading to degradation. Egborge (1994) reported that degradation results in oxygen depletion.

Abowei and George (2009) reported mean dissolved oxygen concentrations range of between 3.72±0.41 and 5.10±0.29 mg/L in Okpoka Creek, Niger Delta, Nigeria. They observed no seasonal and annual variations in the concentration of dissolved oxygen. Abowei *et al*. (2008) also reported mean dissolved oxygen of 7.00±0.06 mg/L in Sombreiro River. Deekae *et al*. (2010) reported that in Luubara Creek, Ogoni land, Niger Delta, the dissolved oxygen concentration values ranged from 4.00 to 7.5 mg/L with a mean of 5.88±0.21 mg/L. They also observed seasonal variation in the dissolved oxygen concentration of Luubara Creek. The dry season values were lower than the wet season values.

Hart and Zabbey (2005) reported that in Woji Creek in the lower Niger Delta dissolved oxygen ranged between 1.6 and 10.1 mg/L. Edogbolu and Aleleye-Wokoma (2007) reported dissolved oxygen range of 0.24-23 mg/L in Ntawoba Creek, Port Harcourt. They also observed high dissolved oxygen values in the dry months.

The highest monthly mean dissolved oxygen occurred in August (7.5 mg/L) during the wet season while the lowest monthly mean occurred in March (6.5 mg/L) during the dry season. Both the spatial and monthly mean values recorded in this study compare favorably with the report of Nwadiaro *et al*. (1982) on the drinking water quality of some rivers in the Niger Delta and Abowei *et al*. (2008) on Sombreiro River and Deekae *et al*. (2010) in Luubara Creek, Ogoni Land. No seasonal difference in dissolved oxygen concentration was recorded during the study. The wet season dissolved oxygen ranged from 6.94-7.14 mg/L while the dry season value ranged from 6.60-7.13 mg/L. The non-seasonality of dissolved oxygen observed in this study is at variance with reports on other water bodies by Ogamba *et al*. (2004), Abowei and George (2009), and Deekae *et al*. (2010). River Sombreiro is a very lotic environment and Boyd (1982) reported that surface agitation of water helps to increase the solubility of dissolved oxygen. The non-seasonality may be attributed to the finding of Abowei (2010) that in rivers and streams the turbulence ensures that oxygen is uniformly distributed across the water and in very shallow streams the water may be super saturated. Oxygen concentration in water is controlled by four factors: Photosynthesis, respiration, exchanges at the air-water interface and the supply of water to the water body or pond (Krom *et al*., 1989; Erez *et al*., 1990). A major part of dissolved oxygen is observed to come from photosynthesis processes and only a small part originates from the atmosphere (Milstein *et al*., 1989). Sombreiro River has thick vegetation cover at the fringes and is well supplied with lotic water all year round.

The biochemical oxygen demand (BOD) of the study area ranged between 2.12±0.07 mg/L and 2.46±0.54 mg/L with a mean value of 2.37±0.44 mg/L. The biochemical oxygen demand follows a similar pattern with the dissolved oxygen with higher values observed at the up stream stations. The mean biochemical oxygen demand value of the study area indicated that the water is not polluted. Clerk (1986) reported that biochemical oxygen demand range of $\geq 2 \leq 4$ does not show pollution while levels beyond 5 mg/L is indicative of serious pollution. The water of the study area is hereby described as fairly clean. Moore and Moore (1976) and Chinda *et al*. (1991) reported that water bodies with biochemical oxygen demand levels of between 1.0 and 2 m. 0 mg/L were considered clean; 3.0 mg/L fairly clean; 5.0 mg/L doubtful and 10.0 mg/L bad and polluted. The BOD values obtained in this study also compares favorably with the reported values of and Abowei and George (2009). Station 1 had the least BOD value of 2.12±0.07 mg/L and is significantly different from the values of stations 2, 3, and 4 at $p<0.01$.

The mean biochemical oxygen demand of Sombreiro River showed seasonal variations. The wet (2.43±0.01 mg/L) and dry (2.20±0.05 mg/L) season values varied significantly at $p<0.01$. Abowei and George, 2009 have earlier reported seasonal variation in BOD in Okpoka Creek, Niger Delta. This was attributed to runoff and human activities.

Akpan and Offem (1993) reported that mean values of BOD in Cross River ranged from 1.03 to 2.35 mg/L; with the lower values occurring downstream. Emmanuel and Onyema (2007) reported BOD range of 14-60 mg/L from the brackish water creek of university of Lagos. Abowei and George (2009) reported that Biochemical Oxygen Demand (BOD) varied from 0.0 to 6.4 mg/L. They also observed that the mean BOD ranged between 1.97±0.28 to 2.69±0.26 mg/L across the stations. They further stated that no seasonal and temporal variations in BOD occurred. Hart and Zabbey (2005) recorded a BOD range of 0.2-98.0 mg/L in Woji Creek in the Lower Niger Delta. Ogamba *et al*. (2004) reported lower wet season BOD values compared to dry season values in Elechi creek. This was attributed to flood and municipal drains depositing wastes into the estuary leading to degradation.

The electrical conductivity of Sombreiro River water recorded in this study ranged between 16.39±2.96 and 18730.58±89.95 μS/cm. The conductivity of station 1 is strikingly different from those of station 2, 3, and 4 because it is a brackish water environment. It is significantly different at $p<0.01$. The result therefore indicates that Sombreiro River has brackish water at station 1 and fresh water at stations 2, 3, and 4. Egborge (1994b) and Ogbeibu and Victor, (1995) reported that conductivity is an index of the total ionic content of water, and therefore indicates freshness or otherwise of the water. The conductivity of the study area compares favorably with report of Boyd (1979) that the conductivity of fresh water varies between 50-1500 μS/cm.

The mean conductivity recorded across the stations of Sombreiro River 4695.86±2885.24 μS/cm. This value is slightly above the value of 4515.3±656.67 μS/cm earlier recorded by Abowei *et al* (2008) in Sombreiro River in the Niger Delta. The highest monthly mean conductivity value (5525.0 μS/cm) for the period of study was recorded in February during the dry season while the lowest value (4154.9 μS/cm) was observed in September during the wet season. This compares favorably with the monthly conductivity values ranging from 920-33100 μS/cm recorded by Abowei and George (2010) in Okpoka Creek, Niger Delta.

The mean conductivity values obtained for the wet (4816.2 μS/cm) and dry (4403.5 μS/cm) seasons were not significantly different at $p<0.01$. The result only showed slight variation in the conductivity values of the two seasons. This is at variance with the significant variations in conductivity obtained by other workers within the Niger Delta (Ekeh and Sikoki 2003; Moses, 1979; Zabbey, 2002; Abowei and George, 2009). The non-seasonality of conductivity in this study may be attributed to lack of concentration of ions by evaporation and steady mineralization of organic matter in the water.

Abowei *et al*. (2008) reported mean conductivity value of 4515.3±656.67 μS/cm in Sombreiro River in Niger Delta. In the Cross River System, Akpan and Offem (1993) reported conductivity range of 6-25 μmbos from the upper to the lower reaches. Ansa-Asare (1992) in Densu River reported conductivity values greater than 300 μS/cm at most of the stations. Ekeh and Sikoki (2003) observed lower conductivity upstream and higher values down stream in New Calabar River. Gerrarth and Denny (1978) recorded conductivity value of 8.1 μS/cm for a coastal lake in Sierra Leone Moses (1979) reported 6-25 μS/cm in the Cross Rivers System.

Seasonal variation of conductivity had been reported by several investigators: Malaya River (Bishop, 1973); Purari River (Petr, 1983); Cape fear Watershed (Mallin *et al*., 1999); Woji Creek (Zabbey, 2002); New Calabar River (Ekeh and Sikoki, 2003) and Abowei and George (2009) in

Okpoka Creek recorded higher conductivity values in dry season than wet season. Bishop (1973) and Petr (1983) attributed dry season rise in conductivity to the concentration of ions by evaporation, coupled with increased mineralization of organic matter.

CONCLUSION

The temperature values recorded in Sombreiro River are considered normal since it is located in the Niger Delta which is described by NEDECO (1980) as humid/semi-hot equatorial area.

The Salinity of Sombreiro river especially at Station 1 ranged from 0.00 - 7.67±2.63% which is a clear indication of fresh water habitat in the upper and middle courses of the river and brackish habitat in the lower course of the river.

The biochemical oxygen demand follows a similar pattern with the dissolved oxygen with higher values observed at the upstream stations.

The mean biochemical oxygen demand value of the study area indicated that the water is not polluted.
Sombreiro River has brackish water at station 1 and fresh water at stations 2, 3, and 4.

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