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Full Length Research Paper

The effects of solid wood waste discharge on the physico-chemical and microbial characteristics of the Warri river

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Water obtained from three locations from September to November, 2010 at the point of discharge of the sawmill wastes into the Warri river (Point 2) and at 100 m before (Point 1) and after (Point 3) the discharge were analyzed using standard methods to determine the effects of the wastes on the physico-chemical and microbial parameters of the River. While mean values for temperature, alkalinity, sulphate, carbonate, heterotrophic bacterial counts, coliform counts and fungal counts decreased from Points 1 to 2 and increased to Point 3, mean values for pH, turbidity, conductivity, total suspended solids, total dissolved solids, total solids, biological oxygen demand, dissolved oxygen, chemical oxygen demand, nitrate and phosphate increased from Points 1 to 2 and decreased to Point 3. The mean values for pH, temperature and biological oxygen demand were within stipulated standards while the values for chemical oxygen demand, turbidity, conductivity and solids were above. There were no statistically significant differences at 95% confidence level for tested parameters between Points 1 and 3 except for pH, nitrate and fungal counts. The discharge of the sawmill wastes into the Warri river had negative effects on the water quality and the presence of luxuriant growths of water hyacinth corroborates this. There is need for governmental agencies to address the effects of the sawmill industry on the water quality of the Warri river.

Key words: River pollution, organic discharge, sawmill wastes, timber industry, physico-chemical parameters.

INTRODUCTION

River pollution is becoming a critical issue of water management in Nigeria, especially in urban and semi urban cities. Many rivers in urban and semi urban areas of Nigeria have been used for disposals of both solid wastes and wastewaters, usually untreated, and are thus adversely polluted. This high pollution status threatens and, in many cases, has already altered the ecological balance of most rivers in Nigeria. Pollution of water by organic discharges in Nigeria is perhaps a serious threat posed to the Nigerian inland waters (Arimoro et al., 2007).

Warri is a town and port in Delta state, southern Nigeria. It lies along the Warri River in the western Niger River delta, 30 miles (48 km) upstream from the port of Forcados on the Bight of Benin. Warri is a major port city in the Niger Delta and serves as the cargo transfer point between the Niger River and the Atlantic Ocean (Microsoft Encarta, 2008). The Warri River serves as a major source of water for drinking, bathing, fishing, washing, and industrial purposes. The timber industry, which obtains its supply of wood from the mangrove swamp, is a lucrative industry in Warri. They are located along the Warri River and they discharge their wastes directly into the river. The locations of the timber industry are often covered with a luxuriant growth of water hyacinth (*Eichhornia crassipes)*, an indication of water pollution. The aim of this research was to determine the physico–chemical quality and microbial load of Warri

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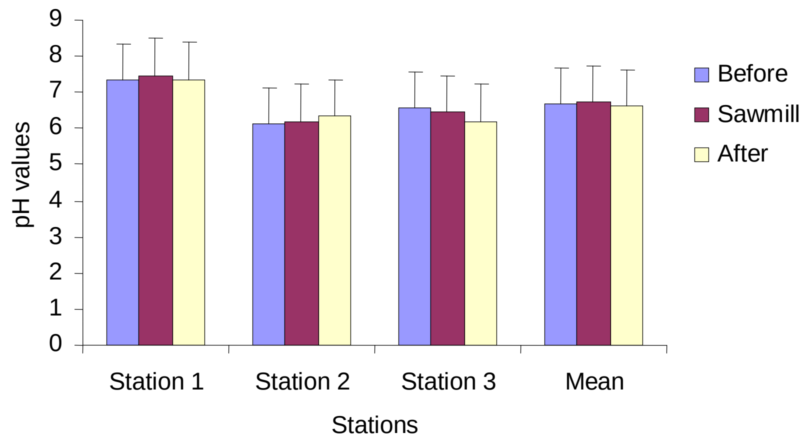

Figure 1. Values of pH for the stations.

River at three locations to determine the effects of the timber industry on the quality of the water.

MATERIALS AND METHODS

Study area

The area under study were sawmills at Udu Bridge, Pessu waterside and Market road, Warri shown in Appendixes I and II.

Collection of water samples

The samples were collected weekly from September to November, 2010 in accordance with the procedure reported by Cheesebrough (2000) at the point of discharge of the sawmill wastes into the river and at 100 m before and after the point of discharge. The water samples were collected asceptically in one litre plastic containers.

Determination of physical parameters

pH

The pH of the water samples was determined immediately after collection using a portable pocket-sized pH meter (HANNA instrument).

Temperature

The temperature of both the sample and control were determined immediately after collection using a 0-100°C thermometer.

Turbidity of samples

The optical densities (560 nm) of incubated samples were determined using a 721-200 VMCS Spectrophotometer.

Electrical conductivity (S/cm)

This was determined using HANNA Instruments HI 9932 Microprocessor Conductivity meter.

Solids

These were determined using methods reported in ASTM Vol 11 (2002).

Determination of chemical parameters

Determination of dissolved oxygen (DO), biochemical oxygen demand (BOD^5), chemical oxygen demand (COD), salinity, alkalinity, nitrates, sulphites, phosphates and carbonates: These were determined using methods reported in ASTM Vol 11 (2002).

Determination of microbial characteristics

Isolation of organisms: This was carried out using the pour plate technique in accordance with the procedure reported in Cowan and Steel (2004). The heterotrophic bacteria, coliform and fungi were cultured respectively on Nutrient agar, MacConkey Agar and Potato Dextrose Agar (PDA) and inoculated plates incubated at 37°C for 24 h for the bacteria and at room temperature (28 ± 2°C) for 48 h for the fungi.

Identification of isolates

This was carried out in accordance with the procedures described by Cowan and Steel (2004).

RESULTS AND DISCUSSION

The mean values of pH for the sampling stations are presented in Figure 1. It was observed that mean values increased from sampling station 1 (6.68) to 2 (6.71) and decreased to station 3 (6.64) representing a decrease of 0.6% from station 1 to 3. This could be due to the effects of the volume of sawmill wastes being discharged into the river and their attendant chemical and biological

Table 1. Statistical analyses at 95% confidence level.

Parameter	Stations 1 and 2 t-test	Stations 1 and 3 t-test	Stations 2 and 3 t-test	F-test
pH	Ho rejected	Ho rejected	Ho accepted	Ho rejected
Temperature	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Turbidity	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Conductivity	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Suspended solids	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Total dissolved solids	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Total solids	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Dissolved oxygen	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Biochemical oxygen demand	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Chemical oxygen demand	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Salinity	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Alkalinity	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Nitrate	Ho rejected	Ho rejected	Ho accepted	Ho rejected
Sulphate	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Phosphate	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Carbonate	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Heterotrophic bacterial counts	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Coliform counts	Ho accepted	Ho accepted	Ho accepted	Ho accepted
Fungal counts	Ho rejected	Ho accepted	Ho accepted	Ho accepted

Statistical analyses at 95% confidence level (Table 1) showed that there was a statistically significant difference between stations 1 and 3. The values were within the 6-9 recommended standards for all industrial effluent discharge into surface water within 15m of outfall by FEPA. These results agree with the pH values of 6 – 7.9 reported in previous research findings on many rivers (Edema et al., 2006; Rim-Rukeh et al., 2006; Arimoro et al., 2007, 2010; Arimoro and Oganah, 2010).

The mean values of temperature for the sampling stations are presented in Figure 2. It was observed that the mean values decreased from station 1 (27°C) to 2 (25.6°C) and increased to station 3 (26.3°C) representing a decrease of 2.48% from Station 1 to 3. Temperature is an important water parameter as it affects rates of metabolism of organisms, dissolution of gases and formation of complexes of various compounds as well as surface tension of liquids. The decrease in temperature could be due to the sawmill wastes being discharged which form a coating on the surface of the water preventing sunlight from penetrating. However, the water temperature values obtained in the study were all within the set standard of 10 - 50°C and also within the <40°C recommended standard for all industrial effluent discharge into surface water within 15 m of outfall by FEPA (FEPA, 1990; WHO, 2002; Anon., 2010a). Statistical analyses at 95% confidence level (Table 1) however showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Adewolu et al. (2004); Arimoro et al. (2007, 2010); Arimoro and Oganah (2010).

The mean values of turbidity for the stations are presented in Figure 3. It was observed that the mean values increased from station 1 (5.7NTU) to 2 (10.10NTU) and decreased to station 3 (6.03NTU) representing an increase of 5.79% from station 1 to 3. The high value for station 2 could be due to the sawmill wastes being discharged into the river. Turbidity usually affects other parameters of water like conductivity, DO, BOD_5 and COD. Statistical analyses at 95% confidence level (Table 1) showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Okokoyo and Rim-Rukeh (2003), Arimoro et al. (2007, 2010), Arimoro and Oganah (2010).

The mean values of conductivity for the stations are presented in Figure 4. It was observed that the mean values increased from station 1 (418.3 S/cm) to 2 (441.22 S/cm) and decreased to station 3 (419.33 S/cm) representing a 0.25% increase from station 1 to 3. The high value for Station 2 could be due to the sawmill wastes being discharged into the river as wood when left for a long time in water undergoes degradation to components that possess electrical conductivity. Statistical analyses at 95% confidence level (Table 1) showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Okokoyo and Rim-Rukeh, (2003), Arimoro and Oganah (2010) and Arimoro et al. (2007, 2010).

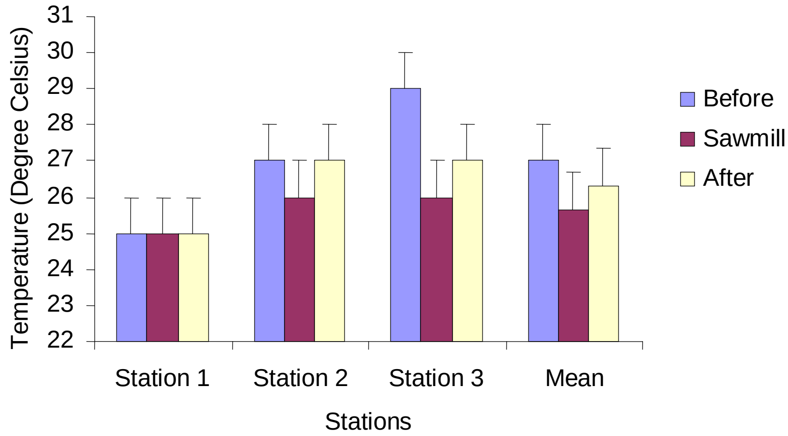

Figure 2. Values of temperature for the stations.

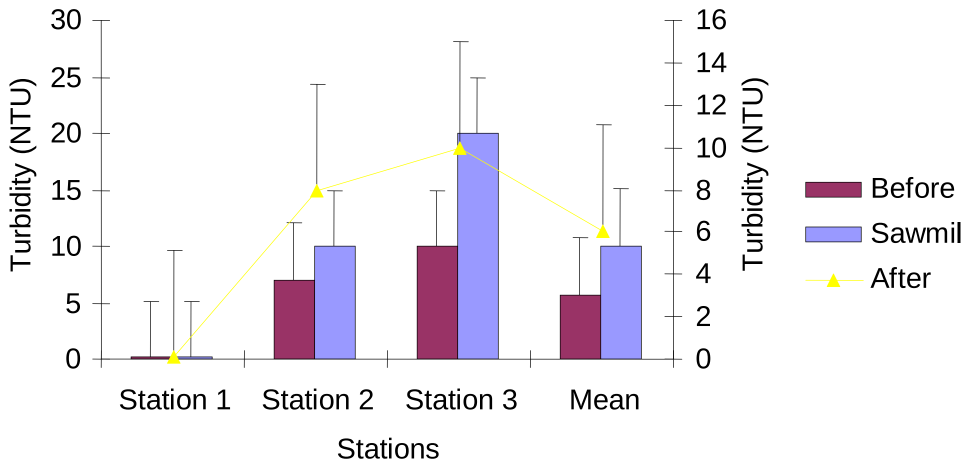

Figure 3. Turbidity values of the stations.

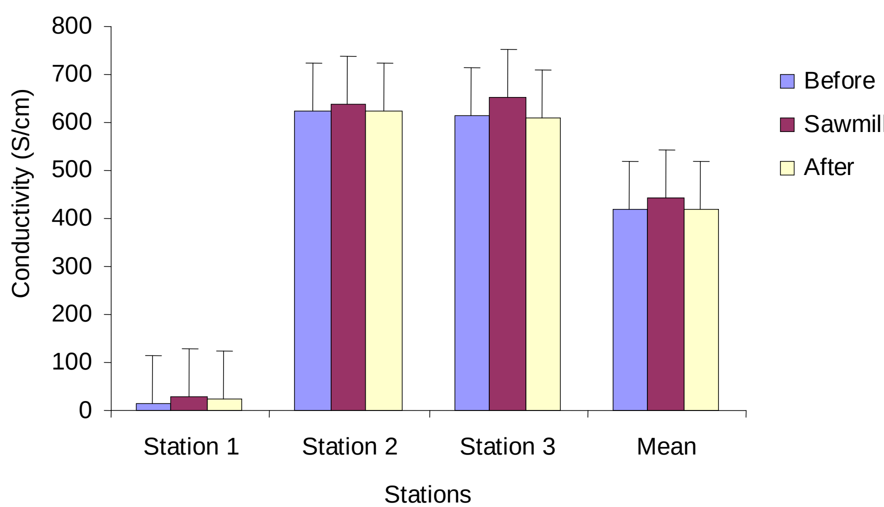

Figure 4. Values of conductivity for the stations.

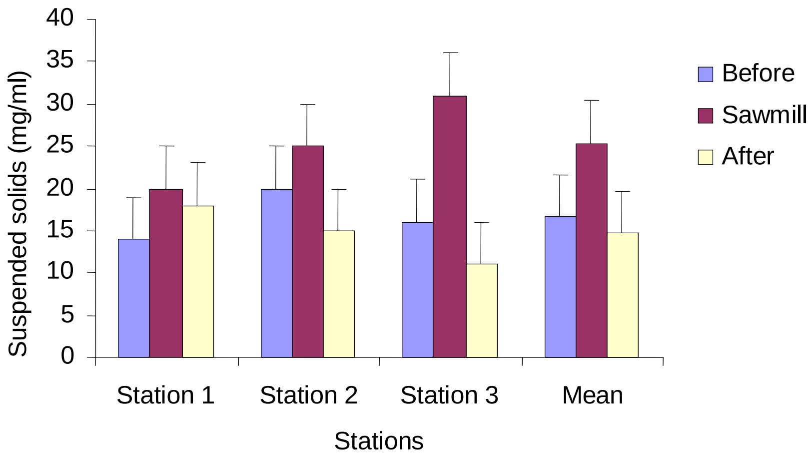

Figure 5. Values of suspended solids for the stations.

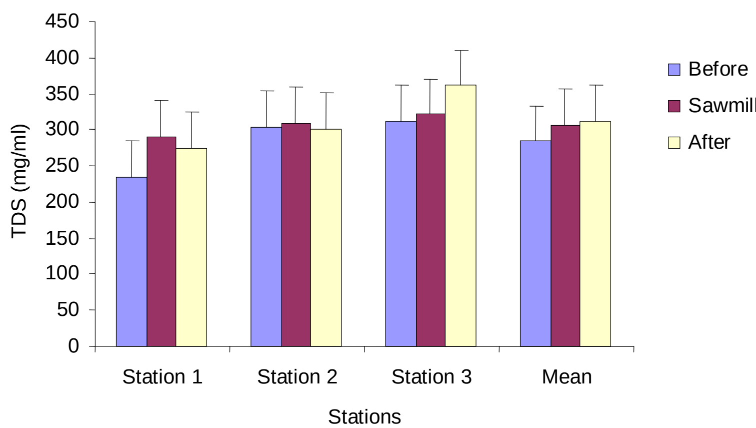

Figure 6. Values of total dissolved solid for the stations.

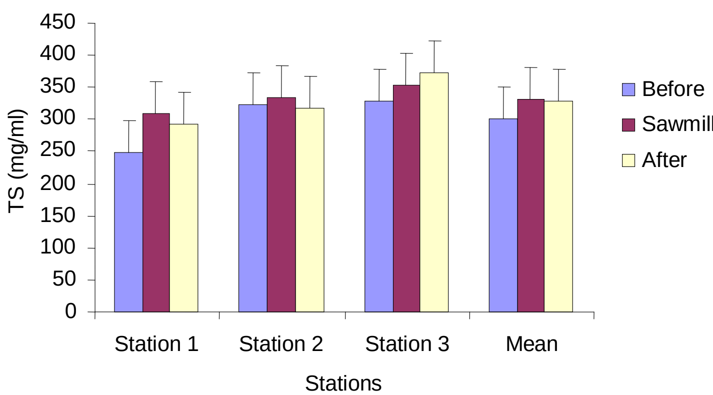

Figure 7. Values of the total solids for the stations.

The mean values of the solids are presented in Figures 5 to 7 for total suspended solids (TSS), total dissolved solids (TDS) and total solids (TS) respectively. It was observed that the mean values for TSS (Figure 5) increased from station 1 (16.67 mg/L) to 2 (24.33 mg/ L) and decreased to station 3 (14.67 mg/ L) representing a

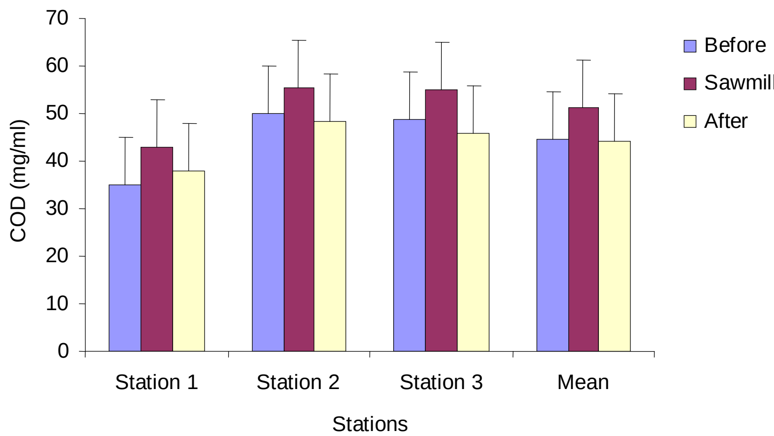

Figure 8. Values of COD for the stations.

12% decrease from station 1 to 3. The values were within the 30 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. The high value for Station 2 could be due to the sawmill wastes being discharged into the river which usually contains much floating particulate matter and sawdust. Statistical analyses at 95% confidence level (Table 1) showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Okokoyo and Rim-Rukeh, (2003), Rim-Rukeh et al. (2006), and Arimoro and Oganah (2010).

It was observed that the mean values for TDS (Figure 6) increased from station 1 (283.67 mg/ L) to 2 (307 mg L) and increased to station 3 (312.67 mg/ L) representing a 10.22% increase from station 1 to 3. The values were within the 2,000 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. The high value for station 2 could be due to the sawmill wastes being discharged into the river as wood when left for a long time in water under degradation to components that possess dissolved readily in water. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Aisien et al. (2010), Arimoro and Oganah (2010) and Arimoro et al. (2007, 2010).

It was observed that the mean values for TS (Figure 7) increased from station 1 (300.31 mg/L) to 2 (332.33 mg/L) and decreased to station 3 (327.33 mg/L) representing 8.99% increase from station 1 to 3. The high value for station 2 could be due to the sawmill wastes being discharged into the river as wood when left for a long time in water under degradation to components such as resin acids, lignins, terpenes, fatty acids and tannins that both float and dissolve readily in water. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Aisien et al. (2010), Arimoro and Oganah (2010, and Arimoro et al. (2007, 2010).

The mean values of Dissolved Oxygen for the stations are presented in Figure 8. It was observed that the mean values for DO (Figure 8) increased from station 1 (300.31 mg/ L) to 2 (332.33 mg/ L) and decreased to station 3 (327.33 mg/ L) representing 8.99% increase from station 1 to 3. The high value for station 2 could be due to the sawmill wastes being discharged into the river as wood when left for a long time in water under degradation to components that both float and dissolve readily in water. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Aisien et al. (2010), Arimoro and Oganah (2010) and Arimoro et al. (2007, 2010).

The mean values of Biological Oxygen Demand$_5$ for the stations are presented in Figure 9. It was observed that the mean values for BOD_5 (Figure 9) increased from station 1 (7.5 mg/l) to 2 (11.83 mg/l) and decreased to station 3 (9.33 mg/l) representing 0.26% increase from station 1 to 3. The values were within the 50 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. However, the cleanliness of the river, based on the BOD_5 values ranged from 5 - 9.9 mg/L, is doubtful (Horan, 2003). The high value for Station 2 could be due to the sawmill wastes being discharged into the river as wood when left for a long time in water under degradation to components that both float and dissolve readily in water. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Okokoyo and Rim-Rukeh (2003); Rim-Rukeh et al. (2006); Aisien et al. (2010), Arimoro and Oganah (2010) and Arimoro et al. (2007,

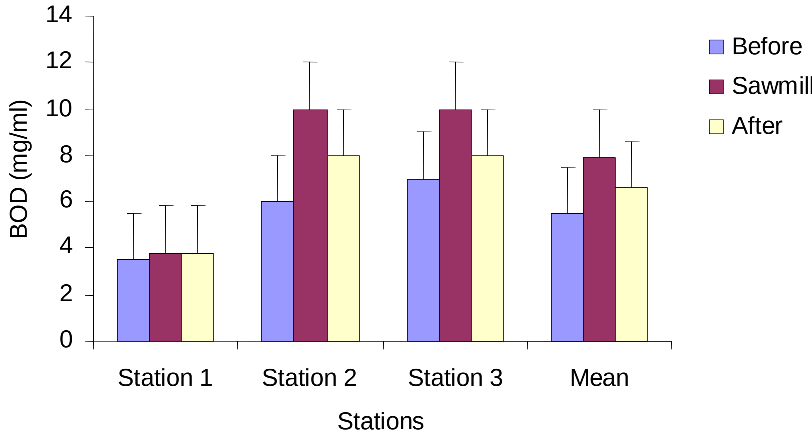

Figure 9. Values of BOD for the stations.

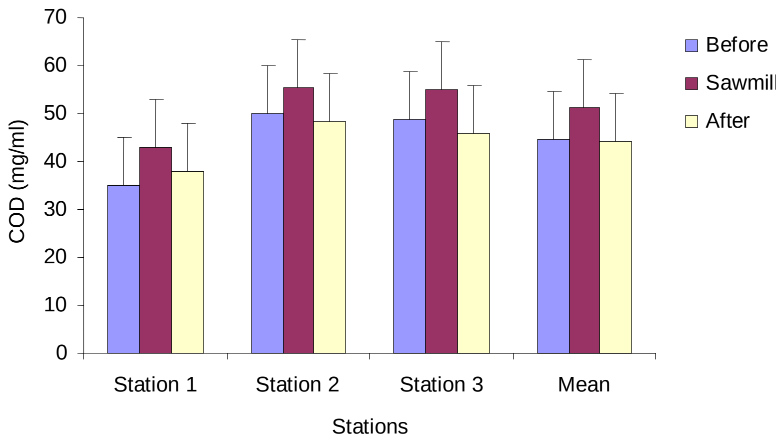

Figure 10. Values of COD for the stations.

2010).

The mean values of Chemical Oxygen Demand for the stations are presented in Figure 10. It was observed that the mean values for COD (Figure 10) increased from station 1 (44.63 mg/L) to 2 (51.07 mg/L) and decreased to station 3 (43.97 mg/L) representing 1.48% decrease from station 1 to 3. The high value for station 2 could be due to the sawmill wastes being discharged into the river. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of previous research (Okokoyo and Rim-Rukeh, 2003; Rim-Rukeh et al., 2006; Aisien et al., 2010; Arimoro and Oganah, 2010; Arimoro et al., 2007, 2010).

The mean values of salinity for the stations are presented in Figure 11. It was observed that the mean values for the same for stations 1 to 3 (0.2 mg/L). The salinity values of the stations were the same for all stations (0.2 mg/L). The Warri River contains fresh water hence the salinity is constant for all the Stations. Statistical analyses at 95% confidence level (Table 1), however, showed that there was no statistically significant difference between stations 1 and 3. These results agree with the reports of Ukpong (2008), Aisien et al. (2010), Arimoro and Oganah (2010) and Arimoro et al. (2007, 2010).

The mean values of alkalinity for the stations are presented in Figure 12. It was observed that the mean values for alkalinity (Figure 12) decreased from station 1 (2.28 mg/L) through 2 (2.2 mg/L) to station 3 (1.89 mg/ L) representing 17.11% decrease from station 1 to 3. The high value in station 1 could be due to high buffering capacity of the river prior to impact with the sawmill wastes. The effect of the wastes discharged into the river is evident in the reduced buffering capacity of the river at

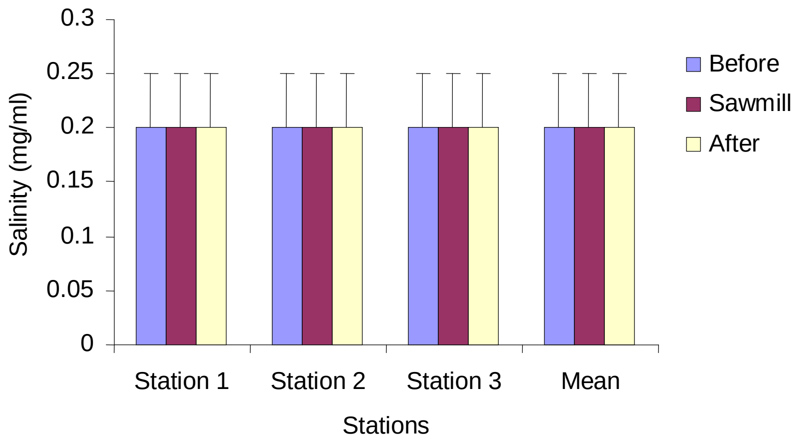

Figure 11. Values of salinity for the stations.

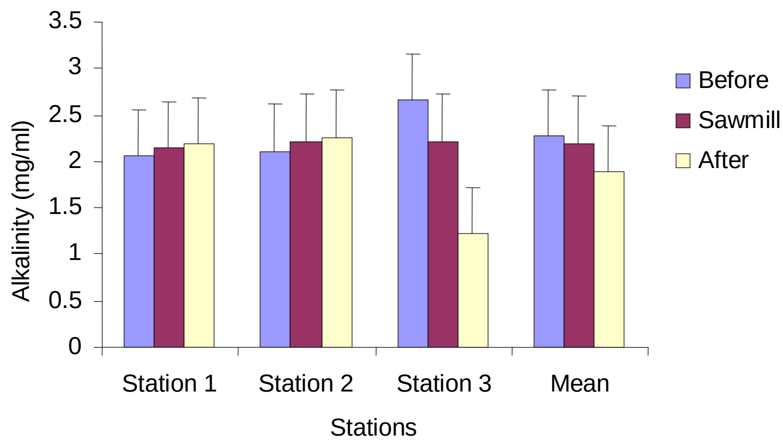

Figure 12. Values of alkalinity for the stations.

station 3. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous research (Okonkwo and Odeyemi, 1985; Okokoyo and Rim-Rukeh, 2003; Rim-Rukeh et al., 2006; Aisien et al., 2010; Arimoro and Oganah, 2010; Arimoro et al., 2007, 2010).

The mean values of nitrate for the stations are presented in Figure 13. It was observed that the mean values for nitrate (Figure 13) increased from station 1 (2.98 mg/L) to station 2 (3.04 mg/L) and decreased to station 3 (0.09 mg/L) representing 96.97% decrease from station 1 to 3. The values were within the 20 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. The high value for Station 2 could be due to the sawmill wastes being discharged into the river. The effect of the wastes discharged into the river is evident in the reduced nitrate content of the river at station 3. Statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous research (Okokoyo and Rim-Rukeh, 2003; Rim-Rukeh et al., 2006; Aisien et al., 2010; Arimoro and Oganah, 2010; Arimoro et al., 2007, 2010).

The mean values of sulphate for the stations are presented in Figure 14. It was observed that the mean values for sulphate (Figure 14) decreased from station 1 (90.42 mg/L) to station 2 (45.15 mg/L) and increased to station 3 (60.13 mg/L) representing 33.50% decrease from station 1 to 3. The values were within the 500 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. The high value for station 2 could be due to the sawmill wastes being discharged into the river. The effect of the wastes discharged into the river is evident in the reduced sulphate content of the river at station 3. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous workers

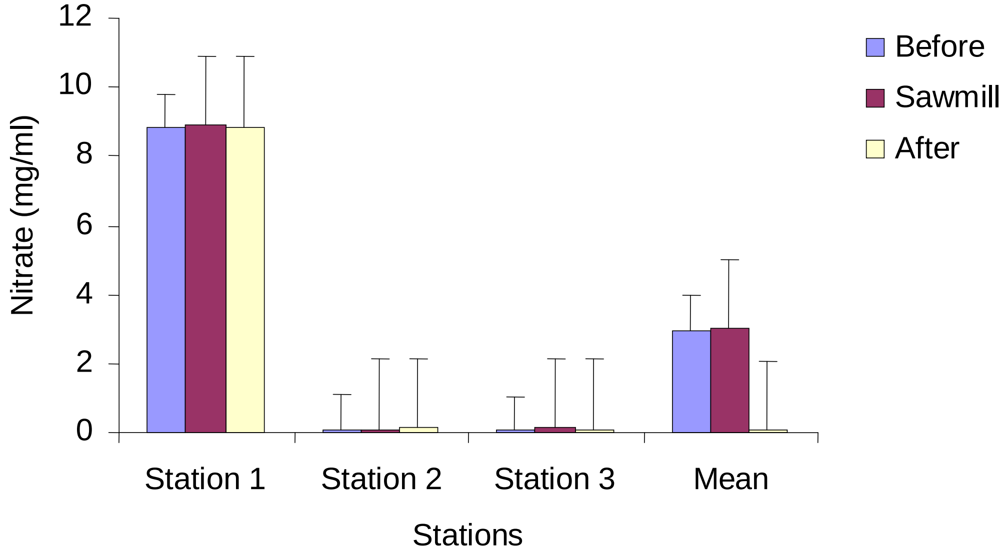

Figure 13. Values of nitrates for the stations.

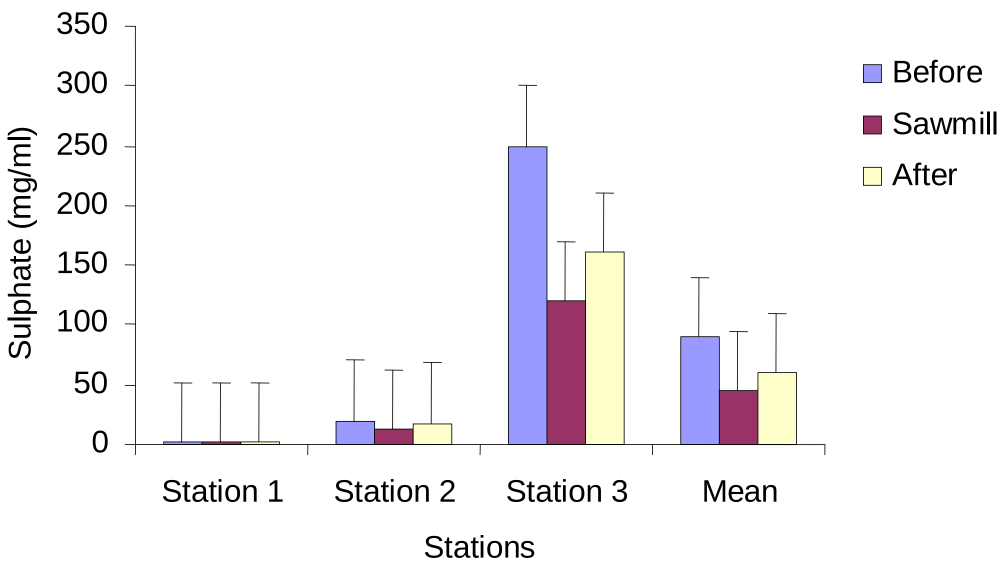

Figure 14. Values of sulphates for the stations.

Aisien et al., 2010; Arimoro and Oganah, 2010; Arimoro et al., 2007, 2010).

The mean values of phosphate for the stations are presented in Figure 15. It was observed that the mean values for phosphate increased from station 1 (0.06 mg/ L) to station 2 (0.07 mg/ L) and decreased to station 3 (0.6 mg/ L) representing no change in value for stations 1 and 3. The values were within the 5 mg/L recommended standards for all industrial effluent discharge into surface water within 15 m of outfall by FEPA. The high value for station 2 could be due to the sawmill wastes being discharged into the river. The river, at the sawmill locations, can be classed as eutrophic as the mean phosphate level is greater than 0.020 mg/L. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous research (FEPA, 1998; Murphy, 2007).

The mean values of carbonate for the stations are presented in Figure 16. It was observed that the mean values for carbonate decreased from station 1 (92.45 mg/L) to station 2 (44.33 mg/L) and increased to station 3 (62.43 mg/L) representing 24.92% decrease from stations 1 to 3. The high value for station 2 could be due

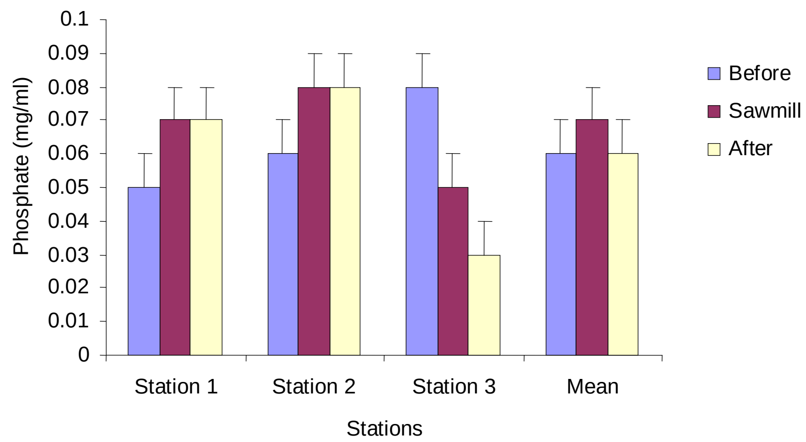

Figure 15. Values of Phosphates for the stations.

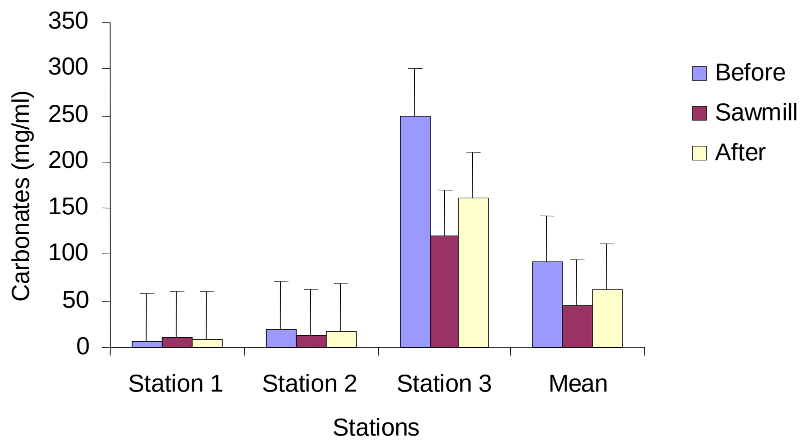

Figure 16. Values of Carbonates for the stations.

(Okokoyo and Rim-Rukeh, 2003; Rim-Rukeh et al., 2006; to the sawmill wastes being discharged into the river. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous research (Okokoyo and Rim-Rukeh, 2003; Rim-Rukeh et al., 2006; Aisien et al., 2010; Arimoro and Oganah, 2010; Arimoro et al., 2007, 2010).

The mean values of heterotrophic bacterial counts (HBC) for the stations are presented in Figure 17. It was observed that the mean values for HBC decreased from station 1 (91.2 Log10cfu/l) to station 2 (46.89 Log10cfu/L) and increased to station 3 (61.59Log10cfu/l) representing 32.47% decrease from stations 1 to 3. The low value for station 2 could be due to the sawmill wastes being discharged into the river resulting in reduction in the microbial load apparently arising from the fact that wood wastes contain cellulolytic materials and only microbial wood degraders can prevail. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous workers (Benka-Coker and Olimani, 1995; Vega et al., 1996; Murphy, 2007; Anon., 2010a).

The mean values of coliform counts (CC) for the stations are presented in Figure 18. It was observed that the mean values for CC decreased from station 1 (18.33 Log10cfu/l) to station 2 (14.95 Log10cfu/l) to station 3 (12.33 Log10cfu/L) representing 32.73% decrease from stations 1 to 3. The decrease in values could result from the fact that coliforms are poor wood degraders. The coliforms observed could be from human feces deposited into the river. No statistically significant difference between stations 1 and 3 at 95% confidence level was observed in Table 1. These results agree with the reports of previous workers (Okonkwo and Odeyemi, 1985; Benka-Coker and Olimani, 1995; Murphy, 2007; Anon., 2010a, b).

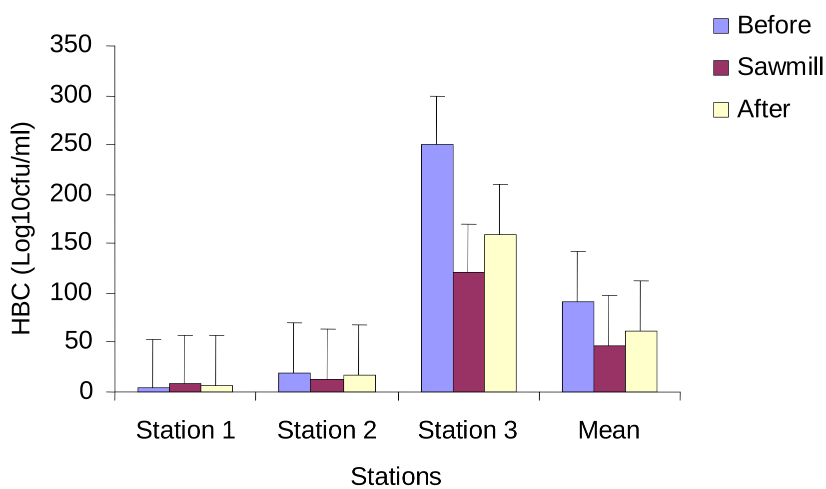

Figure 17. Heterotrophic bacterial counts for the Stations.

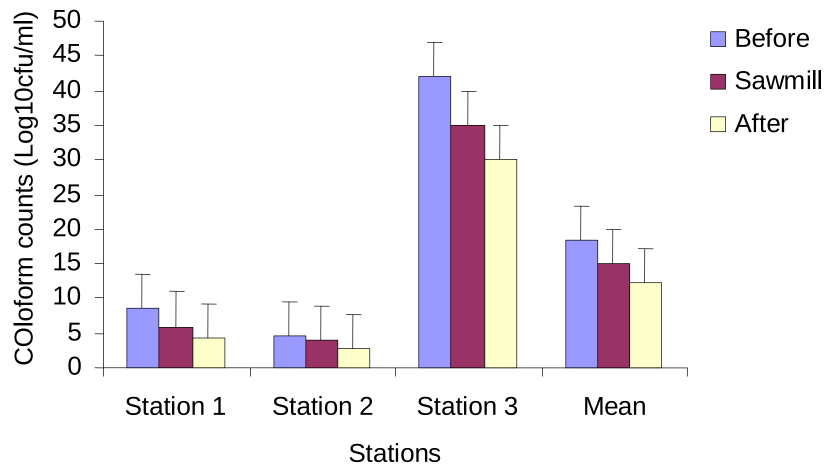

Figure 18. Coliform counts for the stations

The mean values of fungal counts (FC) for the stations are presented in Figure 19. It was observed that the mean values for FC decreased from station 1 (21.37 Log10cfu/l) to station 2 (19.01 Log10cfu/l) to station 3 (8.59 Log10cfu/l) representing 59.80% decrease from stations 1 to 3.

The decrease in values could result from the fact that wood wastes deposited on the river had inhibitory effects on the fungi as not all fungi are wood degraders. Only members of the wood rot fungi are reportedly involved in wood degradation as they possess extra-cellular lignin modifying enzymes – laccase, ligin-peroxidase and Mn-dependent peroxidase (Prescott et al., 2008). The toxic effects of the wood wastes on fungi were evident in the drastic reduction in the fungal counts between station 1 and 3. A statistically significant difference between stations 1 and 2 at 95% confidence level is given in Table 1. These results agree with the reports of previous research (Okonkwo and Odeyemi, 1985; Benka-Coker and Olimani, 1995; Murphy, 2007; Anon., 2010a, b).

Conclusion

The research showed that the activities of the sawmill industry on the Warri river has negative effects on the quality of the water to the extent that the water may be unfit for human consumption. The level of pollution at the study area was high as the river water surface was virtually covered with water hyacinth (*Eichhornia crassipes*), a plant, whose presence in fresh water bodies, reportedly indicates pollution. Thus, there is thus need for governmental agencies to monitor the activities of these sawmills to ensure compliance with set

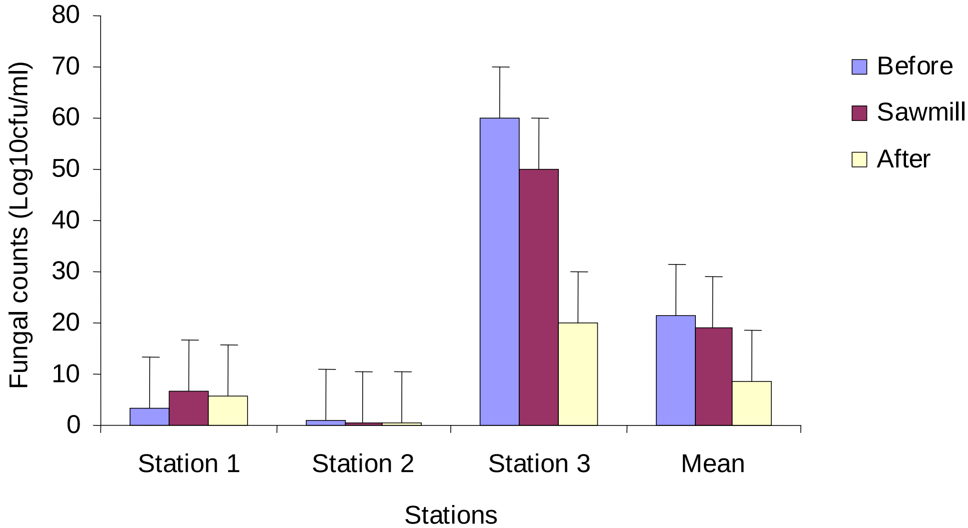

Figure 19. Fungal counts for the stations.

standards by regulatory bodies.

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Appendix I. Location showing the sawmill and logs of wood at Pessu waterside.

Appendix II. Location showing dense growth of water hyacinth and logs of wood**.**