has brought up negative public health, disruption of the aquatic ecosystem, and negative environmental impacts including groundwater contamination and eutrophication of surface water bodies[1]. The disposal of untreated wastewater into the surface water bodies leads to serious problems and poses danger to public health[2]. Failure to treat wastewater according to internationally acceptable standards prior to final disposal has a direct impact on the biological diversity of aquatic ecosystem which could inexorably upset the integrity of our life support systems as a wide range of sectors ranging from urban development, food production and industries exclusively depend on it[3,4]. Sustainable wastewater treatment can help support peri-urban agriculture to reduce water consumption, address food security and enhance livelihood opportunities[5].

River Benue is the main source of water supply for the inhabitants of Makurdi as it is employed for industrial, agricultural and domestic purposes. Presently, physical examination has revealed that industrial and municipal wastewater is channeled into River Benue on a daily basis. It has been established by Akpen and Eze that indiscriminate pollution of the river had resulted into occurrences of water related diseases in the area[6]. The authors reiterated further that typhoid fever, amoebic dysentery and cholera are the water related diseases that are commonly reported in Makurdi area. The pollution of River Benue through indiscriminate disposal of industrial and municipal wastewater is not restricted to the city of Makurdi alone, as have reported that the pollution of water bodies has become a momentous global problem these days[7].

Research studies have indicated that efforts and emphases are being placed on the management of wastewater so as to ensure continuous conformity with permissible standards in the world over[8,9]. This indicates that any wastewater that meets regulated standard upon discharge into water bodies will pose no public health issues. Lack of adequate sanitation would continue to hinder the sustainability of potable water which would in turn increase the spread of diseases and ultimately hamper development[10]. The ultimate goal of wastewater management is tailored towards the protection of the environment in a manner commensurate with public health and socio-economic concerns. Owing to the afore-documented background information, this study was conducted to assess the quality of ricemill wastewater being discharged into river Benue.

Method

Study area

River Benue with its source in the Cameroonian mountains flows westwards into Nigeria. It is the second largest river in Nigeria and measures approximately 310,000 Ha. It is about 1.488 km in length with alluvia fertile flood plains on either banks[11]. It flows through Makurdi and confluences with river Niger at Lokoja in Nigeria. Makurdi is the capital city of Benue state in Nigeria and it is located on Latitude 7041' N and Longitude 80 28' E (Fig 1).

Sampling

Grab samples of the wastewater generated from a ricemill factory situated close to river Benue were collected at the point of final discharge into the river and at twenty (20) meters away from the meeting point of the effluent and the river water. The samples were collected at the aforementioned sampling points in sterilized two (2) liter bottles and preserved in a cooler filled with granular ice to inhibit the activities of microorganisms as established by American Water Works Association [AWWA][12]. The samples were immediately transported into the laboratory for analyses.

Physicochemical and bacteriological analyses

The physicochemical and biological properties; temperature, turbidity, total suspended solids (TSS), pH, conductivity, dissolved oxygen (DO), total organic carbon (TOC),

biochemical oxygen demand (BOD), total heterotrophic count (TCC), nitrate, sulphate and phosphate were determined using standardized methods described by AWWA[12].

Data Analysis

Data obtained were subjected to descriptive statistics. Results were summarized using tables and bar charts. Physicochemical and bacteriological parameters were subsequently compared with permissible standards of WHO (1998, 2006) and NESREA (2011).
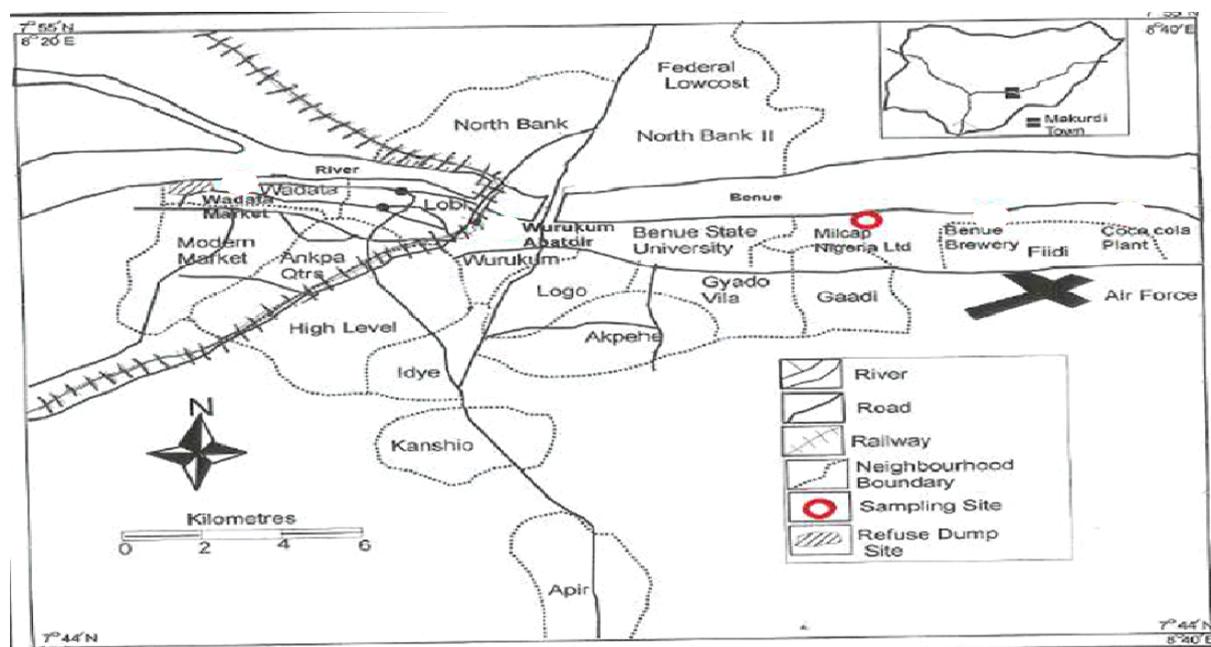

Fig 1. Map of Makurdi, Middle Belt region of central Nigeria showing the sampling site depicted in red colour (Source: Ministry of Lands and Survey, Makurdi)

Results and Discussion

The concentration of nitrate which ranged between the values of 154.6 mg/L -160.0 mg/L in the raw effluent and 80.0 mg/L – 83 mg/L (Tables 1 and 2). The phosphate concentration of the rice mill wastewater varied from a minimum (2.04 mg/L) to a maximum (2.08 mg/L) in sampling point A with a mean concentration of 2.06 mg/L (Table 1). In comparison with sampling point B, the values ranged between 2.04 mg/L and 2.08 mg/L (Table 2). The highest count of heterotrophic bacteria in point A is 1680 cfu/mL (Table 1). The highest count of heterotrophic bacteria in sampling point B is 680 cfu/ml (Table 2).

Table 1. Physicochemical and biological analyses conducted on sampling point A.

Parameters	SSP A1	SSP A2	SSP A3	SSP A4	SSP A5	Mean value
T (ºC)	32.3	34.7	28.6	33.4	32.6	32.3
pH	4.28	5.23	4.32	3.34	4.24	4.28
BOD (mg/L)	2.3	2.1	2.5	2.2	2.3	2.3
COD (mg/L)	4.6	4.8	4.5	4.3	4.6	4.6
DO (mg/L)	3.3	3.4	3.3	3.8	3.2	3.4
TDS (mg/L)	1538	1478	1615	1522	1538	1538
THC (cfu/mL)	1600	1680	1580	1540	1600	1600
Nitrate (mg/L)	157.5	160	155.2	157.8	154.6	157
Sulphate (mg/L)	75	83	69	73	75	75
Phosphate (mg/L)	2.06	2.04	2.05	2.07	2.08	2.06

Note: SSP= Sub sampling point; T= Temperature; TDS= Total dissolved solids; BOD= Biochemical oxygen demand; COD= Chemical oxygen demand; DO= Dissolved oxygen; THC= Total heterotrophic count

The acidic nature of the raw wastewater observed at sampling point A could be attributed to the presence of acidic compounds such as carbonic acid (HCO_3), phosphoric acid present in the raw effluent as well as the excessive use of alum (Al_2O_3) for coagulation of water before it is being used for rice processing. Fondriest Environmental states acidic pH is known to favour the bioavailability of most metals in river systems with its attendant consequences[13]. This author further submitted that low pH levels can encourage the solubility of heavy metals resulting in the release of metal cations into the water rather than being adsorbed into the sediment. The acidic pH obtained in sampling point A has got the capacity to give rise to alga bloom. Similar assertion has been reported by Fondriest Environmental[13]. According to WHO in 1998, the acidic pH values recorded in sampling point A can aid massive death of fishes in river Benue[14]. The pH values recorded in this study revealed its unsuitability for discharge into the environment, and such indiscriminate discharge should be monitored. The results obtained in this study are in agreement with the study that reported pH values of 6.43 – 6.45 confirming the slight acidity of the river close to their study area due to the introduction of effluent from industries within[15]. The pH values ranged from 3.34 to 5.23 with a mean pH (4.28) in sampling point A while it ranged from 6.43 to 8.72 with a mean pH (7.21) in sampling point B (Tables 1 and 2). However, comparisons of the pH values of the sampling points with permissible standards are presented in Fig 2. The highest counts of heterotrophic bacteria in point A and B were 1680 cfu/mL and 680 cfu/mL respectively (Fig 3).

Table 2. Physicochemical and biological analyses conducted on sampling point B

Parameters	SSP A1	SSP A2	SSP A3	SSP A4	SSP A5	Mean Value
T (^{0}C)	33.4	29.6	34.5	33.5	32.6	32.7
pH	6.82	8.72	6.43	6.74	7.32	7.21
BOD (mg/L)	2.1	2.2	2.1	2.0	2.3	2.1
COD (mg/L)	4.2	4.6	3.8	3.6	4.8	4.2
DO (mg/L)	3.3	4.1	3.1	3.0	3.2	3.3
TDS (mg/L)	1468	1348	1586	1473	1466	1468
THC (cfu/mL)	540	608	580	460	512	540
Nitrate (mg/L)	81	83	80	82	81	81.4
Sulphate (mg/L)	25	30	2\	25	18	25
Phosphate (mg/L)	2.06	2.04	2.05	2.07	2.08	2.06

Note: SSP= Sub sampling point; T= Temperature; TDS= Total dissolved solids; BOD= Biochemical oxygen demand; COD= Chemical oxygen demand; DO= Dissolved oxygen; THC= Total heterotrophic count
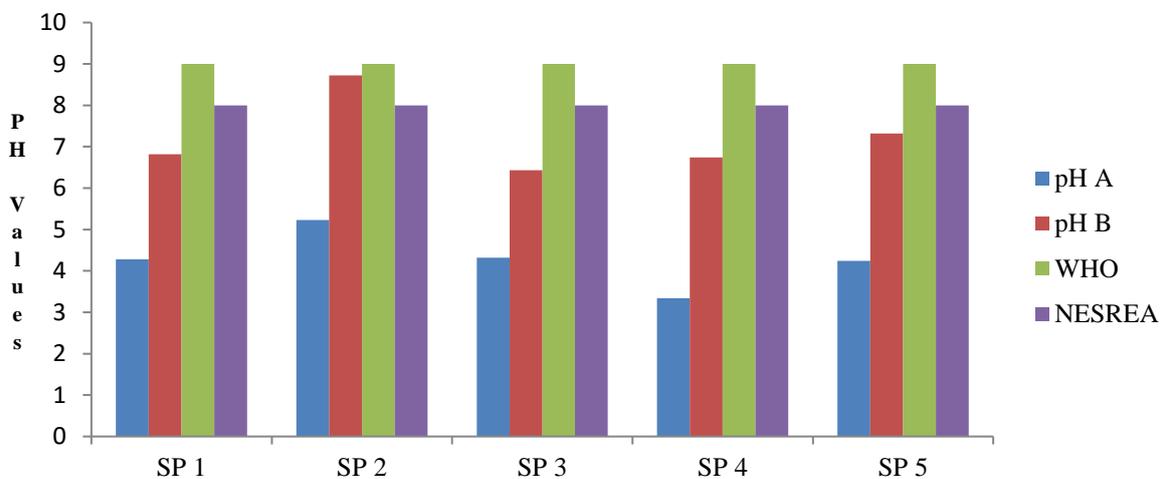

Fig 2. Comparison of pH values of sampling points with permissible standards

The THC results of the two sampling points (A and B) were found to be higher than WHO[14] permissible limits for wastewater (100 cfu/mL at 22°C and 37 cfu/mL at 37°C) fit for discharge into the environment. As done in this study, the conduct of THC is in line with international practice regarding the utmost need for determining the suitability of wastewater meant for final disposal into the environment. The presence of heterotrophic microorganisms in the wastewater studied is in conformity with the report of Biolumix[16].
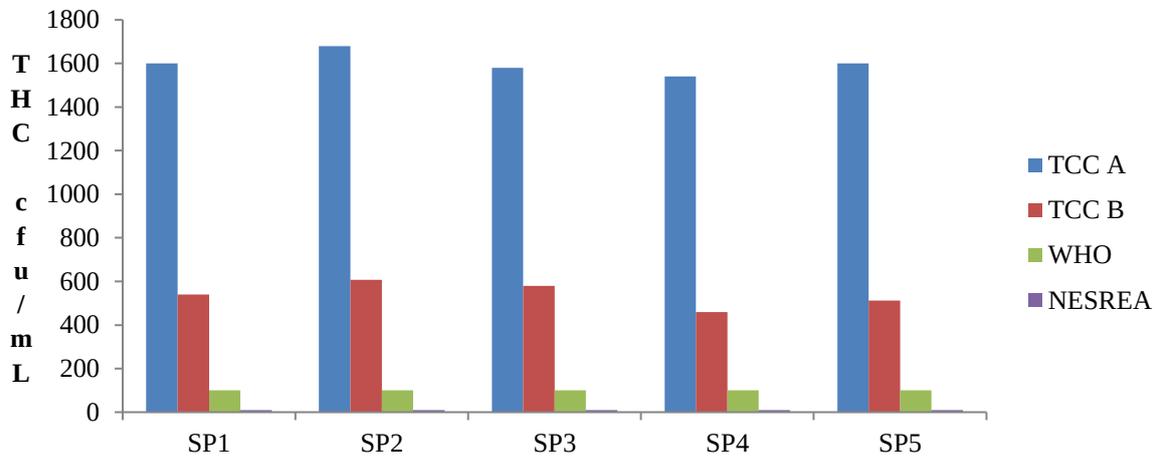
Fig 3. Comparison of THC values of the sampling points with permissible standards

In this study BOD content ranged from 2.1 mg/L to 2.5 mg/L (Fig 4), in point A with a mean value of 2.3 mg/L. In sampling point B, the BOD values ranged from 2.0 mg/L to 2.3 mg/L (Fig 4). Similar results regarding the DO obtained in the sampling points in this study (Fig 6)[17–19]. The increasing anoxic bacterial population recorded in this study have been attributed to influence pH reduction[20,21]. The low DO concentrations recorded in this study are in concord with the submission[22], who reported that low DO in effluent is an indication of high microbial activities in the water due to the presence of biodegradable organic compounds. Excessive nutrient loading can lead to depletion of DO by stimulating algae bloom consequently suffocation and death of aquatic organisms[23].
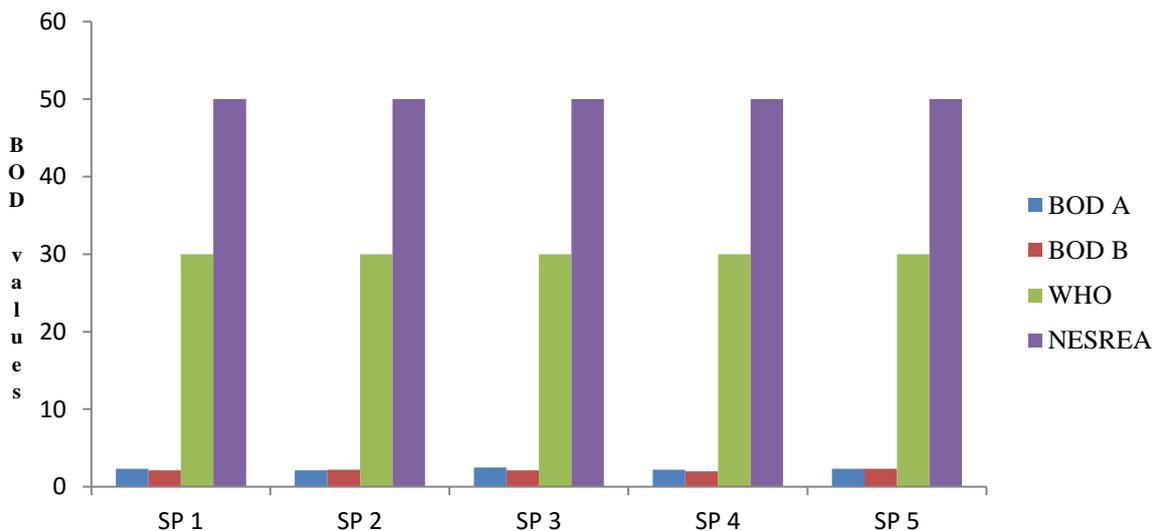
Fig 4. Comparison of BOD values of the sampling points with permissible standards

In this study, the COD values are higher than the BOD values. This could be attributed to some organic materials in the wastewater that might have undergone microbial oxidation.

These results corroborate the findings[24]. Both sampling points (A and B) recorded COD (Fig 5) found to be below the permissible limit (10 mg/L) set by WHO on the quality of effluent fit for discharge into surface water[25]. The results obtained on the COD of the wastewater in this study are in agreement with the study conducted by Pradhan and Sahu[26]. In this study, the mean BOD value recorded in the two sampling points (A and B) is below the allowable WHO limit (30mg/L) and allowable NESREA limit (50 mg/L) (Fig 4). However, these results are contrary to the findings of Ubwa *et al.* (2013) who reported higher BOD that was above permissible limit of recommended standards in their assessment of surface water around Gboko abattoir.
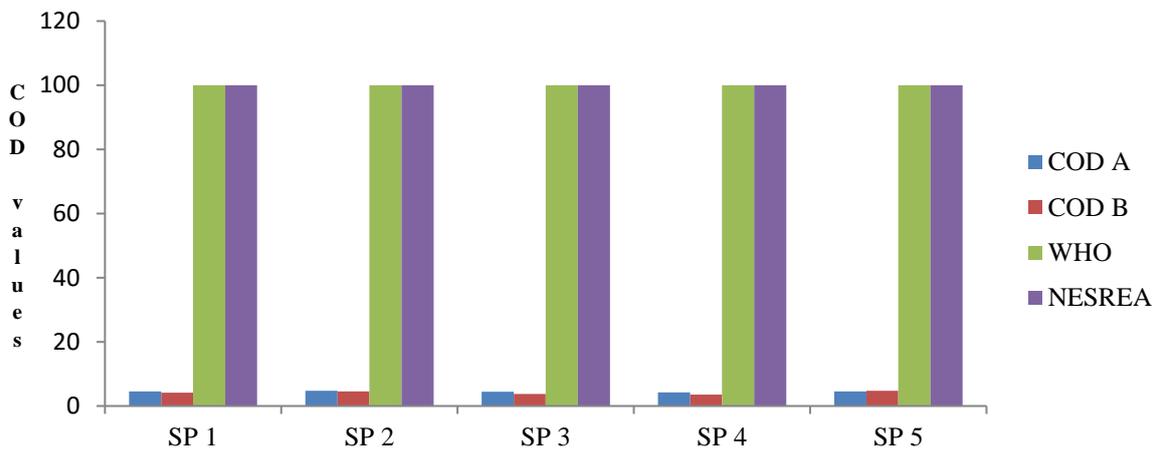

Fig 5. Comparison of COD values of the sampling points with permissible standards

The mean TDS values recorded in sampling points A and B (Tables 1 and 2) are above permissible limits set by WHO (1000 mg/L) and NESREA (1200 mg/L). Water that contains less than 500 mg/L of dissolved solid is considered as fresh water, generally satisfactory for domestic use and other industrial purposes. According to Chhatwal, water that contains more than 1000 mg/L of dissolved solids as witnessed in this study, usually contains minerals that give it a distinctive taste or make it unsuitable for human consumption[27]. This author further submitted that a maximum TDS (400 mg/L) is permissible for diverse fish production thereby indicating that fishes in the receiving river Benue can adversely suffer the effect accruable from excessive TDS recorded in this study. A similar finding recorded study in 2010 on the assessment of TDS in the wastewater of the Raniganj industrial area in India[28].
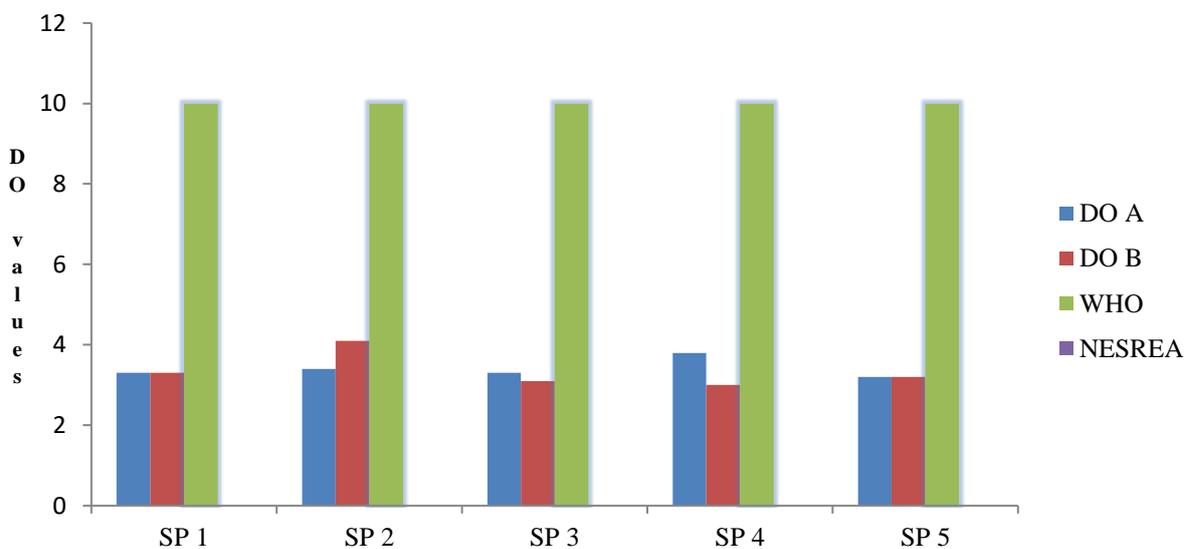

Fig 6. Comparison of DO values of the sampling points with permissible standards

The mean concentrations of nitrate recorded in this study were observed to be high in the river water due to biological decomposition of organic matter present in the wastewater discharged from the ricemill factory. These results are in agreement with the reports that documented nitrate concentrations ranging from 17.2 mg/L to 20.4 mg/L in the wastewater assessed[17,18]. According to Mikuka and Vecera, a high concentration of nitrate in wastewater can be attributed to the high concentration of organic matter content, resulting from the decomposition of protein, and nitrogenous compounds, which upon break down would give rise to simpler substances, including ammonia[29]. Detection of high concentrations of nitrate in the body of water witnessed in this study can certainly lead to eutrophication. However, the phosphate concentrations recorded in the sampling points were below the allowable limits of WHO (5 mg/L) and NESREA (10 mg/L).

Conclusion

The results generated from this study have clearly revealed consistent microbial pollution which was greater in the raw wastewater. The highest THC that was recorded in sampling point A did not conform to permissible limits. Results obtained from BOD, COD, sulphate and phosphate analyses in sampling points A and B were observed to be within the permissible limits. However, results obtained for pH, DO, TDS and nitrate were above the acceptable limits set by WHO and NESREA. However, DO showed lower variations from the permissible limits, but nitrate, TDS and THC recorded higher variations. In case of the raw wastewater samples, higher values of these parameters were recorded indicating its pollution capability. Due to these results, surface water as well as groundwater may get polluted by the wastewater from the ricemill. Therefore, effluent from the ricemill is unsafe for discharge into the water bodies. However the study was limited to the determination of few parameters which were estimated over a short period of time.

Owing to the results recorded in this study, effective treatment of the wastewater with a view to meeting acceptable standards before final discharge into the river Benue to avert pollution of the river is recommended. Public enlightenment campaigns should be intensified to educate residents that solely depend on the river water for their daily water needs on the dangers inherent in taking water from the river without any form of treatment

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Author contributions