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The Impact of Sawmill Activities on Surface Water Quality in the Pessu Market Section of the Warri River

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Abstract
Solid waste serves as a substantial contributor to environmental contamination by introducing chemical substances into the environment in quantities that exceed acceptable limits. This study aims to ascertain the impact of sawmill activities on the surface water quality in the Pessu market section of the Warri River. Surface water samples were collected from 6 sampling points upstream and 6 sampling points downstream. Sampling and analysis of the surface water was done according to standard methods and procedures. The results of this study showed pH in the ranges of 6.5 – 6.91 and 6.81 – 7.09; turbidity ranged from 44.61- 90.89 NTU and 39.88 – 84.20 NTU; iron varied from 2.70 – 5.62 mg/L and 0.55 – 4.89 mg/L; Cadmium ranged from 0.54 – 0.60 mg/L and 0.55 – 0.74 mg/L for the upstream and downstream respectively. Water quality index result revealed that the water is not suitable for drinking. Turbidity, iron, and cadmium exceeded WHO standard limits for drinking water quality. The exceedances observed in this study are an indication that the sawmill activities may have a negative impact on the surface water quality in the study area. It is therefore recommended to carry out measures to mitigate these exceedances observed.

Keywords: Sawmill Activities, Surface Water, Environmental Impact

Introduction

The advancement in technology and industry has undeniably elevated the overall quality of life and increased comfort for humanity. Likewise, the sawmill industry continues to offer employment opportunities and various other advantages[1]. Wood undergoes processing to create a wide range of wood-based products, including plywood, particleboard, fiberboard, wooden implements like tool handles, sports equipment, weaving tools, wooden toys, furniture, and paper production. Hence, the significance of wood cannot be overstated, and it is imperative to seek and apply methods to ensure the sustainability of wood-based products [1, 2]. However, the wood processing carried out in sawmills results in the generation of waste [1].

Solid waste represents a significant source of environmental pollution, introducing chemical substances into the environment beyond their acceptable limits [3]. Manufacturing operations involved in processing raw wood, such as sawmills, paper mills, and furniture manufacturers, are the primary contributors to pollution in Nigeria's waterways [4].

Wood shavings and leachates are responsible for the release of inert solids and toxic pollutants, directly obstructing fish gills and indirectly reducing light penetration. This limitation in productivity contaminates the aquatic environment and weakens the immune systems of aquatic organisms, making fish more susceptible to parasites [5, 6, 7]. Wood residue leachate, characterized by its black color and petroleum-like odor, can cause foaming in water [6]. These leachates are generated when water percolates or flows through wood residue, and these wastes eventually find their way into rivers [7]. The decomposition of wood residue is a slow process, which can result in decades of leachate production, as naturally occurring substances in wood, such as resin acids, lignins, terpenes, fatty acids, and tannins, dissolve from these concentrations [8].Sawmill wood effluents also deplete oxygen in the water, endangering aquatic life and leading to life-threatening consequences [7]. The waste from sawmills can significantly elevate the levels of nitrogen, phosphorus, and total solids in the receiving water body and is subject to run-off [9, 10]. Bodies of water such as rivers, lakes, and oceans are examples of where these pollutants end up.

Surface water is an indispensable natural resource that supports a wide array of activities, including agriculture, industry, transportation, and recreation [11]. The quality of surface water depends on various physical, chemical, and biological attributes, including temperature, pH, dissolved oxygen, and nutrient levels. The presence of contaminants in surface water can have significant repercussions on both human health and the environment [10]. Consequently, managing the quality of surface water is crucial for safeguarding the environment and sustaining human activities. Effective management approaches encompass continuous monitoring of surface water quality. The Water Quality Index (WQI), a rating that demonstrates the interplay of various water parameters on overall water quality, was used to assess the river's water quality in the context of surface water quality [12].

The Pessu market area along the Warri River stands as one of the largest markets in the region, with prominent sawmill operations. This region is notorious for its elevated levels of water pollution, which pose substantial risks to both human health and the environment. Residents have voiced concerns about the dwindling fish population, while traders and transporters have lamented how sawmill waste obstructs the river, hindering their ability to transport people and goods from one location to another. This study seeks to investigate and establish the impact of sawmill activities on the surface water quality of the Pessu River.

The Study Area

The research site is situated within Delta State, Nigeria, specifically within the Niger Delta area. Warri, renowned for its oil industry, is positioned in the southern region of Nigeria, commonly referred to as the south-south region. Pessu Market is located within the jurisdiction of Warri Southwest Local Government Area (LGA), which constitutes one of the four LGAs in the broader Warri region of Delta State. The Warri River interconnects with the Forcados River and Escravos River via Jones Creek, forming a vital part of the lower Niger Delta region. This geographical area predominantly features rainforests with occasional swamplands and boasts an abundance of fruit trees, palm trees, and valuable lumber trees. The primary livelihoods of the local population encompass fishing, agriculture, animal husbandry, transportation, trade, sawmill operations, and civil service employment.Fig. 1 shows the map of the study area showing the sampling points along Pessu River.

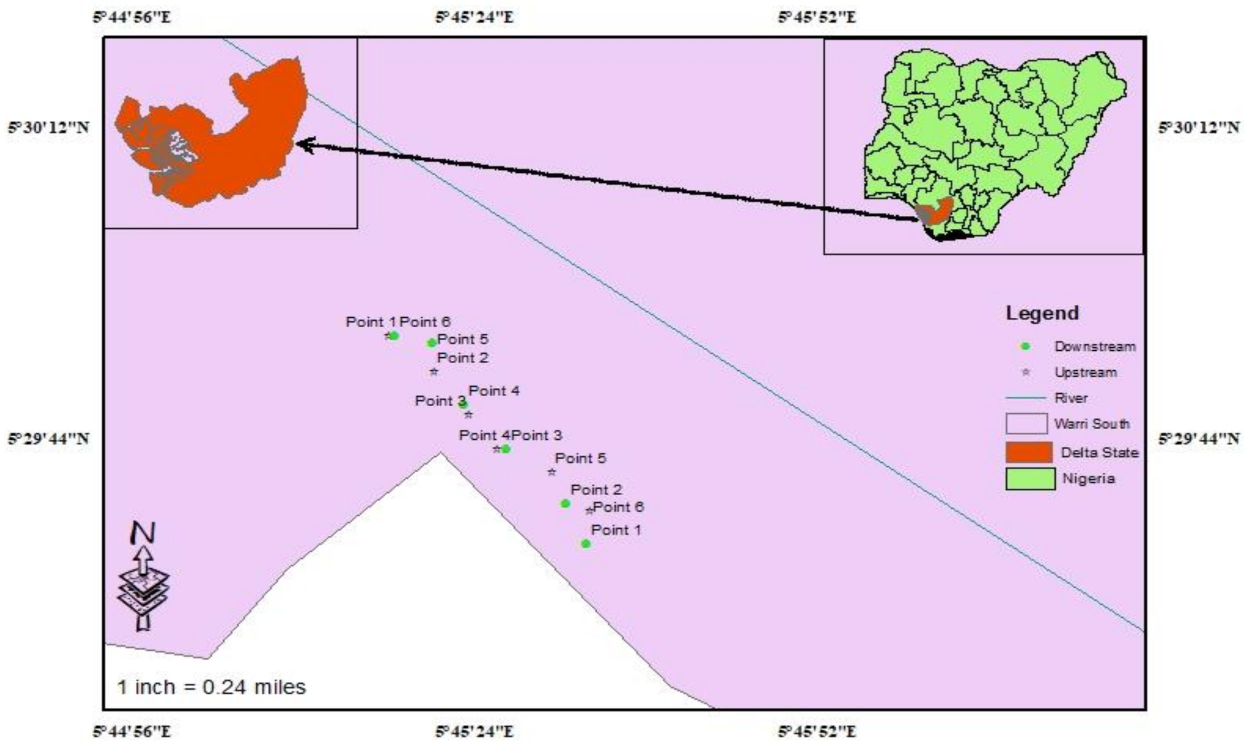

Fig. 1: Map of the Study Area.

Surface Water Sampling

A total of twelve (12) surface water samples were gathered from the upstream and downstream (100m) areas of the Pessu Market Section of the Warri River in Delta State. The collection process involved using two-litre plastic containers, 100ml plastic containers and BOD bottles that had been treated beforehand by washing with and rinsed with distilled water. Prior to sample collection, the plastic containers were rinsed with the relevant water sample to be collected. Water samples were taken in replicates by immersing the container below the water surface and allowing it to overflow. On-site (in-situ) analysis was conducted for various water quality parameters, including pH, conductivity, dissolved oxygen, total dissolved solids (TDS), and temperature. The samples were preserved by cooling at approximately 4°C. For metal analysis, the samples were preserved using 1 ml of nitric acid (HNO3) to lower the pH to ≤ 2. All ex-situ analysis was carried out at Dukoria Laboratory Ltd in Effurun, Delta State.

Analytical Methods

Table 1 show the method adopted in the determination of the various parameters.

Table 1: Analytical methods for determination of the various parameters[13]

Parameters	**Analytical Methods**
pH	Electrometric method (APHA - 4500-H+)
Temperature, ^{0}C	Electrometric method (APHA-4500-H+)
Conductivity, µS/cm	Electrometric method (APHA-4500-H+)
Total Suspended Solids (TSS), mg/L	Gravimetric method (APHA-2540-D)
Total dissolved solids (TDS), mg/L	Gravimetric method (APHA 2540 C)
Salinity (Cl-), mg/L	Electrical conductivity method (APHA 2520-B)
Turbidity, NTU	Nephelometric method (APHA – 2130-B)
Nitrate, mg/L	Ultraviolet Spectrophotometric Method (APHA 4500-NO_3^-B)
Sulphate, mg/L	Turbidity method (APHA-4500 SO42-E)
Ammonia, mg/l	Direct nesslerization method(4500-NH_3C)
DO, mg/L	Azide modification method (APHA – 4500 -O C)
BOD, mg/L	5-day method (APHA 5210B)
COD, mg/L	Closed reflux, titrimetric method (APHA 5220 C)
Calcium, mg/L	Atomic Absorption Spectrophotometry (APHA 3400)
Magnesium, mg/L	Atomic Absorption Spectrophotometry, (APHA 3400)
Metals,mg/L	Atomic Absorption Spectrophotometry, (APHA 3400)

Source: APHA, 2012.

Digestion of Water Samples for Heavy Metals Analysis

Digestion was carried out, a process of acid digestion which involves dissolving a sample into solution by adding acids (HNO3) and heating until complete decomposition of the sample to release the analyte (metals). Two Hundred and fifty (250) mL of the water sample was transferred into 25 ml beaker and 5.0 mL conc. HNO_3 was added. The solution was evaporated or heated to about 10 mL, making sure that the sample did not heat to dryness. The mixture was then allowed to cool after which it was filtered using a filter paper. The filtrate was poured into a 25 mL calibrated volumetric flask and made up to the meniscus with appropriate volume of distilled water. The absorbance of the metal was determined by aspiration of the sample digest into an Atomic Absorption Spectrophotometer (Buck Scientific AAS model 210) [13].

Statistical Analysis

This study result was subjected to descriptive statistical analysis to compute the mean and standard deviation of the obtained data. One-way ANOVA was used to determine the significant difference between the downstream and the upstream. Microsoft excel was used to calculate the water quality index. Other software programs used in this study includes SPSS, Kyplot 5.0, and Microsoft Excel Office 365 was utilized.

Results and Discussions

Results

pH

The pH of the surface water samples ranged from 6.5 – 6.91 across all the sampling locations taken upstream while the downstream samples had pH values ranging from 6.81 – 7.09. There was no statistically significant difference between the pH values obtained upstream and downstream. The study area had a mean pH value of 6.81± 0.14.

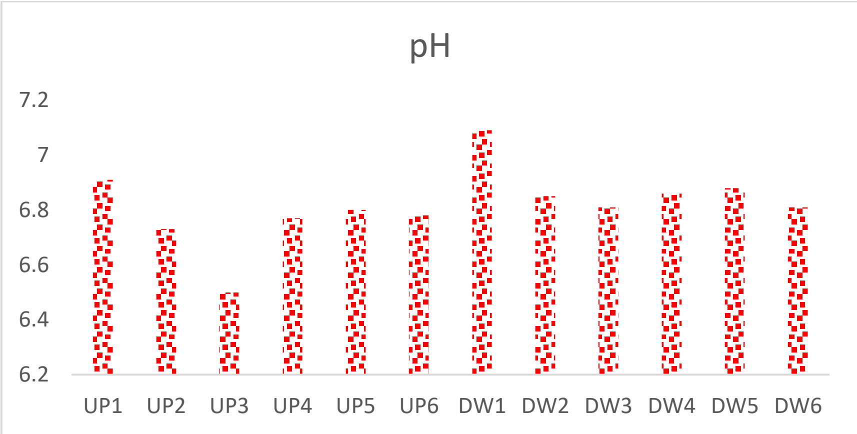

Fig.2: Variations of pH for surface water in the Study Area.

Turbidity

Turbidity which is the measure of the cloudiness of water was high in all upstream sampling locations as it ranged from 44.612 – 90.889 NTU, while the samples collected downstream ranged between 39.984 – 84.205 NTU. The turbidity values obtained upstream and downstream did not show any statistically significant difference. In the study area, the average turbidity value was 61.58 ± 16.49 (Table 4.3). Turbidity Values in the upstream and downstream of the study area exceeded WHO standard [14] recommended limits for drinking water quality.

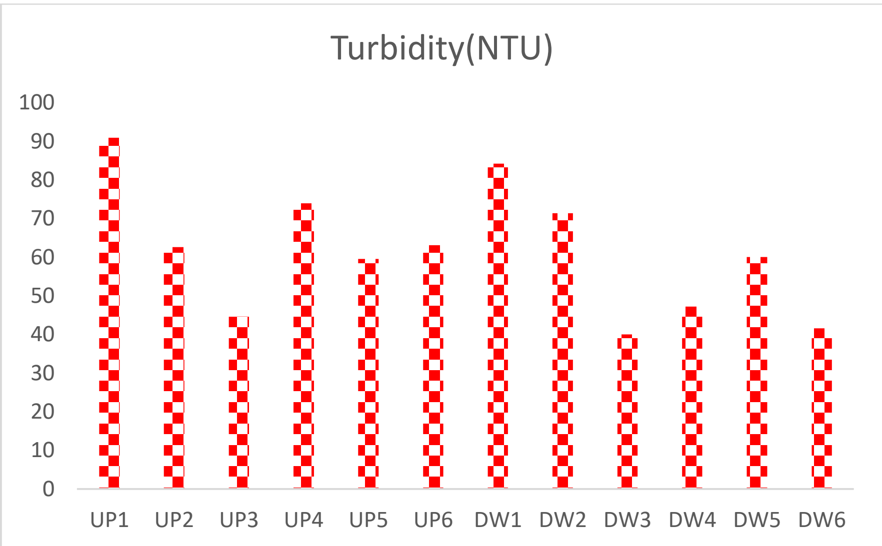

Fig.3: Variations of Turbidity for Surface Water in Study Area

Total Dissolved Solid (TDS), Salinity, and Total Suspended Solids (TSS)

The TDS levels of the surface water collected had a mean value of 27.91 mg/L across all the sampling stations. upstream and downstream ranged from Salinity was relatively low as concentration ranged between 12.93 - .17.06 for samples collected upstream and 12.93 – 16.55 mg/L for samples collected downstream. The total Suspended Solids for upstream samples were 12.085 – 19.485 mg/L and6.905 – 23.185 mg/L for the samples collected downstream. There was no statistically significant difference between TDS, salinity, and total suspended solids measured upstream and downstream in the study area.

Fig. 4: variations of TDS, salinity and TSS for surface water in the Study Area

Fig.5: Variations of TDS, Salinity and TSS for Surface Water in the Study Area

Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD)

The DO levels of the surface water bodies ranged from 2.4-7.40 mg/L across all the sampling stations upstream and at downstream. The BOD levels of the surface water upstream varied between 1.8 – 3.0 mg/L and 1.4 – 3.8 mg/L in the downstream sector. The COD levels ranged from 11.0 – 20 mg/Lin all sampling locations upstream and downstream.

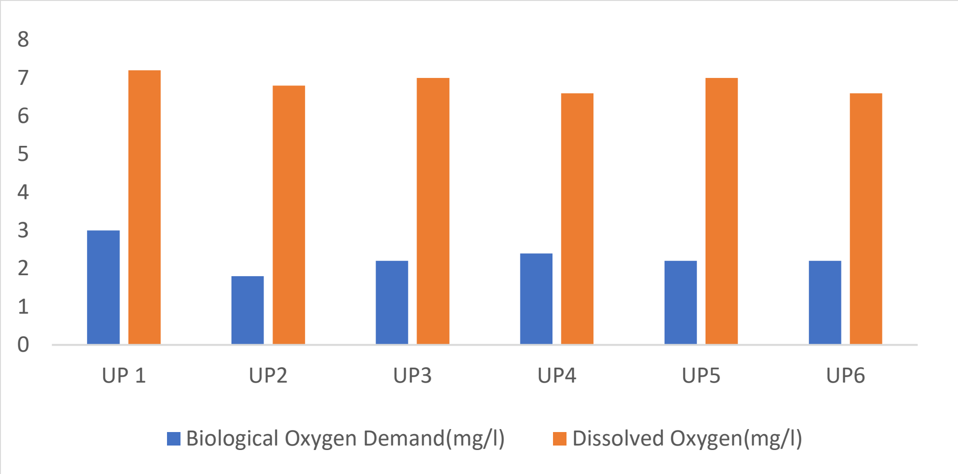

Fig.6: Variations of BOD and DO for Surface Water in the Study Area

Sulphate, Nitrate and Ammonia

The concentrations of Sulphate, Nitrate and Ammonia in surface water collected upstream were 24.622 – 34.431 mg/L; 0.470 – 0.599 mg/L and 0.617 – 0.926 mg/L while the samples collected downstream ranged between 20.618– 48.018 mg/L; 0.470 – 1.042 mg/L and 0.508 – 0.991 mg/L respectively.

Calcium and Magnesium

Calcium was below detection limit of <0.001 in all the samples collected downstream. However, it ranged between 1.197 – 1.863 in just two points collected upstream. Magnesium ranged from 1.295 – 1.933 in the upstream samples and 1.170 – 1.838 mg/L of the downstream sector.

Table 2: Physicochemical Characteristics of Warri's River Surface Water.

PARAMETER	UP1	UP2	UP3	UP4	UP5	UP6	WHO, 2011
Ph	6.91	6.73	6.50	6.77	6.80	6.78	6.5-8.5
Temperature(ºC)	26.50	26.30	26.40	26.10	26.00	26.50	-
Electrical Conductivity(µs/cm)	59	52	50	58	67	54	250
Total Dissolved Solids(ppm)	29.00	26.00	25.00	29.00	33.00	27.00	1000
Salinity as CL^-(mg/l)	15.00	13.44	12.93	15.00	17.06	13.96	250
Total Suspended Solids(mg/l)	19.485	13.935	12.085	15.415	18.745	18.375	50
Turbidity (NTU)	90.889	62.609	44.612	73.921	59.524	63.123	5
Gross Organics							
Biological Oxygen Demand(mg/l)	3.0	1.8	2.2	2.4	2.2	2.2	4-6
Dissolved Oxygen(mg/l)	7.2	6.8	7.0	6.6	7.0	6.6	6
Chemical Oxygen Demand(mg/l)	20	15	20	20	11	12	10

Inorganics (Anions and Cations)							
Sulphate(mg/l)	34.031	28.425	24.622	34.431	25.623	25.222	250
Nitrate(mg/l)	0.526	0.526	0.470	0.599	0.470	0.507	50
Ammonia(mg/l)	0.617	0.656	0.630	0.900	0.926	0.652	0.5
Calcium(mg/l)	1.863	1.197	<0.001	<0.001	<0.001	<0.001	100
Magnesium(mg/l)	1.933	1.295	1.329	1.516	1.609	1.312	30

Table 3: Physicochemical Characteristics of Warri River Surface Water.

PARAMETER	DW1	DW2	DW3	DW4	DW5	DW6	WHO, 2011
pH	7.09	6.85	6.81	6.86	6.88	6.81	6.5-8.5
Temperature(ºC)	26.30	26.40	26.50	26.40	26.30	26.40	-
Electrical Conductivity(µs/cm)	65	61	50	52	53	52	250
Total Dissolved Solids(ppm)	32.00	30.00	25.00	26.00	27.00	26.00	1000
Salinity as Cl^-(mg/l)	16.55	15.51	12.93	13.44	13.96	13.44	250
Total Suspended Solids(mg/l)	23.185	20.595	9.495	10.235	9.125	6.905	50
Turbidity (NTU)	84.205	71.350	39.984	47.183	60.038	41.527	5
Gross Organics							
Biological Oxygen Demand(mg/l)	2.2	1.4	3.8	2.0	2.6	1.8	6
Dissolved Oxygen(mg/l)	7.4	5.6	6.8	7.2	5.0	2.4	4-6
Chemical Oxygen Demand(mg/l)	20	20	15	20	20	16	10
Inorganics (Anions and Cations)							
Sulphate(mg/l)	37.034	38.235	48.018	25.422	29.827	20.618	250
Nitrate(mg/l)	0.968	1.042	0.932	0.470	0.599	0.599	50
Ammonia(mg/l)	0.987	0.991	0.539	0.530	0.678	0.508	0.5
Calcium(mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	100
Magnesium(mg/l)	1.838	1.336	1.665	1.257	1.457	1.170	30

Heavy Metals Result of Warri River Surface Water

The concentrations of iron, cadmium and Nickel in surface water collected upstream were 2.704 – 5.626 mg/L; 0.542 – 0.600 mg/L and 2.718 – 3.574 mg/L while the samples collected downstream ranged between 0.554 – 4.896 mg/L; 0.558 – 0.740 mg/L and 1.606 – 1.995 mg/L respectively. Lead was below detection limit of < 0.001 in all the samples collected downstream and upstream. Chromium was below detection limit of < 0.003 in all the samples collected downstream and upstream. Cadmium and iron values in the upstream and downstream exceeded WHO standard limit for drinking water quality.

Table 4: Heavy Metals Analysis of Warri River Surface Water.

Heavy metals	UP1	UP2	UP3	UP4	UP5	UP6	WHO, 2011
Lead(mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Iron(mg/l)	5.626	2.704	3.690	5.600	3.514	3.267	0.3
Cadmium(mg/l)	0.600	0.563	0.566	0.544	0.595	0.542	0.003
Nickel(mg/l)	<0.001	<0.001	<0.001	3.574	2.718	<0.001	0.02
Chromium(mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.05

Table 5: Heavy Metals Analysis of Warri River Surface Water.

Heavy metals	DW1	DW2	DW3	DW4	DW5	DW6	WHO, 2011
Lead(mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.01
Iron(mg/l)	4,128	0.554	4.896	1.877	2.947	2.415	0.3
Cadmium(mg/l)	0.566	0.557	0.558	0.585	0.565	0.740	0.003
Nickel(mg/l)	1.606	<0.001	<0.001	1.969	<0.001	1.995	0.02
Chromium(mg/l)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.05

Water Quality Index

In this study, the Weighted Arithmetic Water Quality Index (as represented by Equation 1) was employed for the assessment of surface water quality, following the methodology outlined by Chandra *et al*. [15]. The evaluation of the study area's water quality was conducted using the classification system (shown in table 6) introduced by Nong *et al*. [16]. Table 7 provides the outcomes of the Water Quality Index (WQI) analysis of the study area.

Equation 1:

WQI = ((Σw n* q n)/Σ w n) ……………… (i)

Table 6: Water quality classification based on water quality index (WQI) values.

Water quality value	Water quality
91-100	Excellent
71-90	Good
51-70	Moderate
26-50	Poor
0-25	Very poor

Source: (Nong *et al.*,2020)

Table 7: Table showing result of water quality index of the Study Area

Sampling Points	Water Quality Index Level	Water Quality Status
Pessu Upstream 1	15253.72	Unsuitable for drinking
Pessu Upstream 2	14230.12	Unsuitable for drinking
Pessu Upstream 3	14486.46	Unsuitable for drinking
Pessu Upstream 4	13729.65	Unsuitable for drinking
Pessu Upstream 5	14994.09	Unsuitable for drinking

Pessu Upstream 6	13723.60	Unsuitable for drinking
Pessu Downstream 1	14487.94	Unsuitable for drinking
Pessu Downstream 2	14224.77	Unsuitable for drinking
Pessu Downstream 3	14235.82	Unsuitable for drinking
Pessu Downstream 4	14735.82	Unsuitable for drinking
Pessu Downstream 5	14484.67	Unsuitable for drinking
Pessu Downstream 6	18800.77	Unsuitable for drinking

Discussion

The ideal pH range for fish in surface water can vary depending on the species of fish. However, most freshwater fish thrive in a pH range of 6.1 to 8.0. It's important to note that different fish species have specific pH preferences within this range, and some may be more tolerant of pH fluctuations than others. pH values observed in this study suggest a slightly acidic to neutral environment and the pH values in the study area are within this optimum range for growth and survival of fishes. A similar pH was reported previously [6].

The impact of high turbidity levels in surface water can be significant, as it can reduce the penetration of light into the water, negatively affecting aquatic plants and animals [17]. High turbidity levels can also interfere with water treatment processes, as sediment and other particles can clog filters and reduce treatment efficiency. The high turbidity values measured at upstream locations and downstream locations suggest that the sawmill activities may be introducing sediment or other particles into the water. However, other factors such as natural sedimentation, erosion, or other anthropogenic activities could also contribute to the observed turbidity differences.

The influence of sawmill activities on the TDS, salinity, and TSS of surface water could be attributed to the discharge of sawdust and chemicals into the water. The results show that TDS and salinity levels were within acceptable limits, but the TSS levels were relatively high (as shown in table 1 and Table 2). High TSS levels could lead to reduced light penetration in the water, affecting the growth of aquatic plants and the survival of fish and other organisms that depend on them. Additionally, the accumulation of TSS can lead to sedimentation and clogging of waterways, reducing the water's capacity to transport sediments and nutrients. Previous studies have reported similar results [18] and found that sawmill activities led to increased levels of TDS, turbidity, and TSS in a river.

The sawmill activities, sawdust, and chemicals released into the surface water may have contributed to the decrease in DO levels downstream, which could have negative impacts on aquatic life. The concentrations of Chemical Oxygen Demand (COD) in surface water sources typically fluctuate, ranging from under 20 mg/L in pristine, uncontaminated waters to surpassing 200 mg/L in bodies of water that receive discharges or effluents [19]. COD observed in the study area is relatively high. The elevated COD levels in both upstream and downstream sectors suggest highly oxidizable organic substances, which could lead to oxygen depletion, algal blooms, and eutrophication, resulting in adverse effects on aquatic organisms and other receptors. Heavy metals are considered top-priority contaminants due to their elevated toxicity and their tendency to remain persistent in the environment [20].
The evelated levels of iron and cadmium in the study area is an indication of anthropogenic influence on the surface water quality.

The study suggests that sawmill activities may have a slight impact on the turbidity levels of surface water. The sawmill activities may have introduced acidic or basic substances, sediment, other particles, sawdust, and chemicals into the water, affecting the water quality. The study shows that the downstream samples had a drop in DO levels compared to the upstream samples. These results suggest that sawmill activities may contribute to water pollution and that urgent measures are necessary to mitigate their impact on the environment and public health.

Conclusion

The findings of this study highlight the need for immediate action to address the issue of sawmill pollution. The results of this study revealed that the water sources around sawmills are contaminated with various pollutants as observed in elevated levels of turbidity, cadmium, and iron. These pollutants pose significant health risks to individuals who use this water for domestic and agricultural purposes. The water quality index revealed that the water is not suitable for drinking. Further studies are required to assess the long-term effects of exposure to sawmill-contaminated water and to identify additional sources of contamination. Overall, this study emphasizes the importance of protecting our natural resources and underscores the need for responsible and sustainable industrial practices.

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