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Original Research Article

Assessment of the Impact of Auto-mechanic Workshop on Groundwater Quality in Central Business District, Oxbow Lake, Swali, Bayelsa State, Nigeria

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Abstract

Groundwater contamination near automobile workshops is a growing environmental concern due to the leaching of heavy metals and other pollutants into the soil and water sources. This study aims to assess the physicochemical and heavy metal characteristics of groundwater in the Central Business District of Oxbow Lake, Swali, Bayelsa State, before and after treatment. Physicochemical parameters, including pH, total dissolved solids (TDS), electrical conductivity, temperature, chemical oxygen demand (COD), biological oxygen demand (BOD), and heavy metal concentrations (Fe, Cu, Pb, Ni, and Mn), were analyzed before and after treatment. The results show that pH increased from 6.80 ± 0.02 to 7.70 ± 0.02, remaining within the permissible limits of 6.5–8.5 (WHO) and 6.6–9.0 (NSDWQ). Total dissolved solids (TDS) ranged from 122 ± 1.5 to 141 ± 1.5 mg/L, and conductivity reduced from 238 ± 2.0 to 221 ± 2.0 µS/cm, both well below the regulatory limits. Temperature varied marginally from 27.4 ± 0.1°C to 27.8 ± 0.1°C. Chemical oxygen demand (COD) and biological oxygen demand (BOD) increased from 0.58 to 1.06 mg/L and 0.45 ± 0.01 to 0.71 ± 0.01 mg/L, respectively. Heavy metal analysis revealed that Iron concentrations were significantly reduced after treatment, from 0.36 ± 0.01 mg/L to below the detection limit (<0.001 mg/L) slightly exceeded the WHO and NSDWQ limit of 0.3 mg/L, while manganese (0.14–0.42 mg/L) exceeding the WHO guideline. Copper concentrations dropped below the detection limit (<0.001 mg/L) after treatment, from an initial 0.50 ± 0.01 mg/L. Both nickel and lead were below the detection limit (<0.001 mg/L) before and after treatment, indicating zero contamination from these metals. Despite the low concentration observed for the various parameters, continuous monitoring and control measures is recommended.

Keywords: Groundwater contamination, auto-mechanic workshop, heavy metals, physicochemical parameters, water quality, Swali.

INTRODUCTION

Groundwater is a crucial resource for domestic, agricultural, and industrial purposes, particularly in areas where surface water is scarce or contaminated. It is found almost everywhere and constitutes approximately two-thirds of the world's freshwater supply, with over 98% of the available freshwater stored in the pores and fractures of rock strata [1]. In many communities, water supply is primarily derived from groundwater, surface water, and rainwater. However, the rapid expansion of urbanization and industrial activities has raised significant concerns about groundwater quality, especially in regions with inadequate environmental regulations. To be safe for human consumption, water must be free from harmful microorganisms, toxic contaminants, and excessive mineral or chemical concentrations [2].

Groundwater serves as the primary drinking water source for over half of the global population [3]. However, increasing human activities, particularly those associated with auto-mechanic workshops, pose a significant threat to groundwater quality. Automobiles, which are essential for the transportation of people and goods, require regular maintenance and servicing to ensure optimal performance [4]. These necessary servicing activities take place in auto-mechanic workshops, where various operations—including vehicle repairs, spare parts sales, painting, welding, battery repairs, rewiring, and tire replacement—are conducted [5, 6].

Despite their economic importance, auto-mechanic workshops generate significant environmental pollutants, including used engine oil, lubricants, heavy metals, and petroleum hydrocarbons. These contaminants can seep into the soil, infiltrate groundwater aquifers, and compromise water quality. The contamination of groundwater by these pollutants poses serious health and environmental risks, making it imperative to assess the extent of such pollution and its implications.

Previous studies have reported substantial groundwater contamination in areas with a high concentration of auto-mechanic workshops in Nigeria [5, 7-10]. Elevated levels of hydrocarbons and heavy metals beyond permissible limits have been observed in groundwater sources near such facilities, raising concerns about their suitability for human consumption. In Yenagoa, where reliance on groundwater is high, understanding the impact of auto-mechanic workshops on water quality is crucial for public health and environmental management. However, there is limited research on the specific impact of auto-mechanic workshops on groundwater quality in the Central Business District of Oxbow Lake, Swali. This study aims to assess the extent of groundwater contamination in this area by evaluating key physicochemical parameters and heavy metal concentrations. The findings will provide valuable data for policymakers, environmental agencies, and public health officials to implement appropriate measures for groundwater protection and sustainable urban planning.

METHODOLOGY

Description of Study Area

The location of this study is the Central Business District, Oxbow-Lake. It is located between Longitude (006^{o} 17^{I} 07.3^{II} E, 006^{o} 17^{I} 03.6^{II} E) and Latitude (04^{o} $54^{'}20.3^{''}$ N, 04^{o} $54^{'}$ $23.1^{''}$ N) in the central part of Yenagoa, around the Swali area, Bayelsa State. The Oxbow lake covers several hectares, through exact size measurements and a natural lake formed from the meandering Num River (Figure 1).

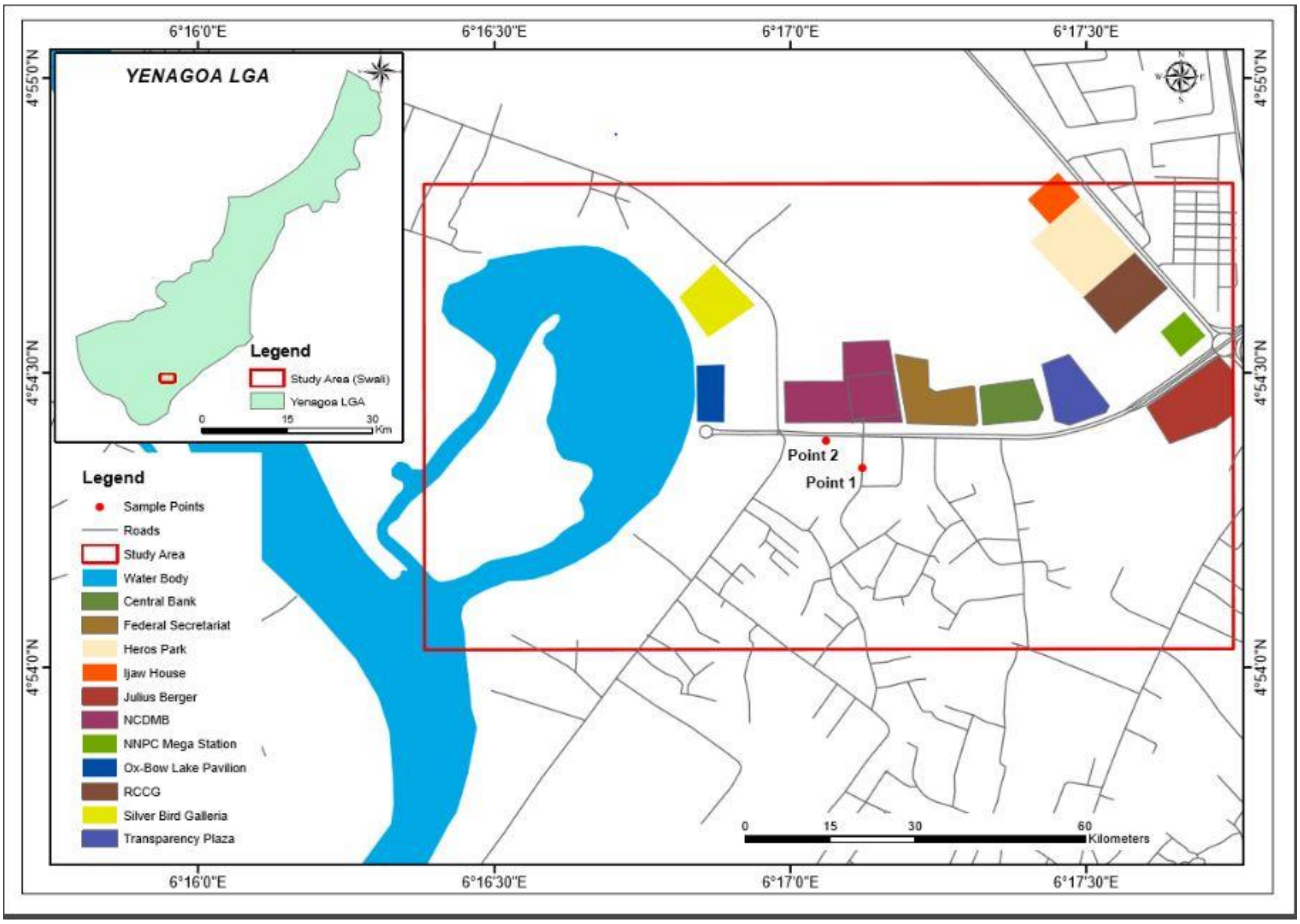

Figure 1: Map of Study Area, Yenagoa, Bayelsa State showing sampling points and Rivers

Sample Collection and Preparation

Water samples were collected using pre-cleaned and homogenized plastic bottles from a borehole located near an automobile repair shop (mechanic workshop) in the Central Business District. Sampling was conducted in triplicate in two phases: before and after treatment. In the first phase, an untreated water sample was collected and transported to the laboratory for filtration and subsequent physicochemical and metal analysis. In the second phase, a treated water sample was obtained following a reverse osmosis (RO) purification process. The RO system employed a semi-permeable membrane that permitted the passage of water while restricting larger molecules such as salts, minerals, and other impurities. This process was facilitated by a pressure pump, which conveyed the purified groundwater into a designated storage reservoir (plastic tank) for further analysis.

Physicochemical Analysis of Borehole water samples

The physicochemical properties of borehole water samples were analyzed before and after treatment to assess water quality. Key parameters, including pH, temperature, total dissolved solids (TDS), electrical conductivity (EC), chemical oxygen demand (COD), biological oxygen demand (BOD), and chloride (Cl^-) were analyzed by physical means using Hanna digital/electronic device (Hanna instruments HI 98129).

Heavy Metal Analysis

The instrument was calibrated using a blank and each metal analyzed. Heavy metal concentrations (Fe, Ni, Cu, Pb and Mn) were determined using Flame Atomic Absorption Spectrophotometry (FAAS) (GBC 908 PBMT, Australia Model).

3.2.3 Statistical analysis

The data obtained in this study were analyzed using descriptive statistical methods in Microsoft Excel to calculate the mean, standard deviation, and variance. The concentrations of the analyzed heavy metals were compared with the WHO [11] and NSDWQ [12] recommended guideline values for drinking water quality standards.

Physico-Chemical Parameters of the Groundwater Samples

Table 1 presents the physicochemical characteristics of groundwater collected near a mechanic workshop before and after treatment, alongside the permissible limits set by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality. The results indicate variations in water quality parameters following treatment, which are essential for evaluating the effectiveness of the remediation process. The pH of the groundwater sample was slightly acidic at 6.80, potentially due to the presence of dissolved carbon dioxide, organic acids, or other contaminants commonly associated with automobile workshop effluents. After treatment, the pH increased to 7.70, indicating a shift towards neutral conditions. This change suggests the effective removal or neutralization of acidic components, enhancing the water's stability and making it more suitable for consumption. Overall, the values falls within the WHO recommended range of 6.5 – 8.5 NSDWQ range of 6.6-9.0 for drinking water. The TDS level reduced from 141 ± 1.5 mg/L before treatment to 122 ± 1.5 mg/L after treatment, indicating the effective removal of dissolved inorganic and organic substances. This is well below the WHO and NSDWQ permissible limit of 500 mg/L for drinking water, indicating that the treatment process further enhanced water purity. The presence of TDS in water can have various effects on human health and the environment. High levels of TDS can lead to an unpleasant taste, odor, or color in the water, which can make it less appealing to drink [10]. The groundwater temperature slightly decreased from 27.8°C before treatment to 27.4°C after treatment. While NSDWQ does not specify a guideline value for water temperature, WHO suggests an acceptable range of 30–32°C. The measured temperatures are below this range, implying minimal thermal influence from anthropogenic activities. The temperature range observed were very close to the values observed by Adewoyin *et al*., [13] who observed a temperature range (26.83±0.76 to 28.67±0.29°C) of groundwater in Ibadan metropolis. Temperature fluctuations can influence microbial growth and oxygen solubility, potentially affecting water quality. Higher water temperatures can reduce oxygen content and may contribute to odor formation [14].

RESULTS AND DISCUSSION

Table 1: Physicochemical characteristics of groundwater collected near an automobile (mechanic) workshop before and after treatment

Parameters	Before Treatment	After Treatment	WHO Standard	NSDWQ Standard
pH	6.80 ± 0.02	7.70 ± 0.02	6.5 – 8.5	6.6-9.0
TDS (mg/L)	141 ± 1.5	122 ± 1.5	250-500	500
Conductivity (µS/cm)	238 ± 2.0	221 ± 2.0	500	1000
Temperature (°C)	27.8 ± 0.1	27.4 ± 0.1	30–32°C	-
COD (mg/L)	0.58 ± 0.01	1.06 ± 0.01	4.50	-
BOD (mg/L)	0.45 ± 0.01	0.71 ± 0.01	4.0	-
Chloride, Cl (mg/L)	73 ± 1.0	67 ± 1.0	200	-

Values are presented as mean and standard deviation (Mean±SD) of triplicate determination

Electrical conductivity is the ability for water to conduct electric current and is also a function of the number and types of dissolved solutes in the water [15, 16]. Electrical conductivity values decreased from 221 ± 2.0 µS/cm before treatment to 238 ± 2.0 µS/cm after treatment, staying below the WHO permissible limit of 500 µS/cm and the Nigerian Standard for drinking water quality NSDWQ limit of 1000 µS/cm. The slight increase in conductivity may be due to dissolved ions introduced during treatment. Compared to previous studies, the observed EC was higher than the values reported by Nebo *et al.*, [16] and Opara *et al.*, [9], lower than those recorded by Shittu & Ojo [10], and comparable to the findings of Adewoyin *et al.*, [13]. Since conductivity indicates the concentration of dissolved ions and can influence the taste of drinking water, the low conductivity observed in this study suggests that the water is free from any undesirable taste [17].

The COD concentration increased from 0.58 mg/L before treatment to 1.06 mg/L after treatment, with a mean of 0.82 mg/L, while BOD increased from 0.45 mg/L to 0.71 mg/L. Both parameters remain significantly below the WHO permissible limits of 4.50 mg/L and 4.0 mg/L, respectively. The chloride concentration increased from 67 ± 1.0 mg/L before treatment to 73 ± 1.0 mg/L after treatment. These levels remain below the WHO guideline of 200 mg/L, indicating no significant contamination from salt intrusion or industrial effluents. It was also lower than the values obtained by Shittu & Ojo, [10]. Chloride levels in a water body impacts the odour and taste in drinking water and can result in gastrointestinal diseases such as stomachache and diarrhoea in toxic concentrations. Excess chloride in groundwater can lead to a salty taste and potential corrosive effects on plumbing.

Heavy Metal Concentrations

The heavy metal contamination of water samples before and after treatment are shown in Table 2. Manganese levels also increased after treatment, from 0.14 ± 0.01 mg/L to 0.42 ± 0.01 mg/L, exceeding the WHO guideline of 0.4 mg/L. While manganese is an essential nutrient, elevated manganese concentrations in drinking water have been associated with neurological disorders, particularly in children [18]. The increase in manganese after treatment may be due to the dissolution of manganese oxides or the use of manganese-based chemicals during the treatment process.

Table 2: Heavy metals contamination of groundwater collected near an automobile (mechanic) workshop before and after treatment

Parameters	Before Treatment (mg/L)	After Treatment (mg/L)	WHO Standard	NSDWQ Standard
Manganese, Mn	0.14 ± 0.01	0.42 ± 0.01	0.4	-
Iron, Fe	0.36 ± 0.01	<0.001	0.3	0.3
Copper, Cu	0.50 ± 0.01	<0.001	0.5-2.0	1.5
Nickel, Ni	<0.001	<0.001	0.02	0.02
Lead, Pb	<0.001	<0.001	0.01	0.01

Values are presented as mean and standard deviation (Mean±SD) of triplicate determination

Iron concentration in the groundwater before treatment was 0.36 ± 0.01 mg/L, slightly exceeding the NSDWQ and WHO limit of 0.3 mg/L. After treatment, iron was successfully reduced to below the detection limit (<0.001 mg/L), indicating the effectiveness of the treatment process in removing iron. The iron concentrations observed in this study differ from those reported by Adewoyin *et al.*, [13] for groundwater in an auto-mechanic workshop in Ibadan Metropolis, Nigeria, where iron levels ranged from 0.23 ± 0.41 mg/L to 10.90 ± 10.31 mg/L. Copper levels were also reduced to below the detection limit (<0.001 mg/L) after treatment, from an initial concentration of 0.50 ± 0.01 mg/L. The initial concentration was within the WHO acceptable range of 0.5–2.0 mg/L but below the NSDWQ limit of 1.5 mg/L. The effective removal of copper indicates that the treatment process is capable of addressing this contaminant, possibly through adsorption or ion exchange [19].

Both nickel and lead were below the detection limit (<0.001 mg/L) before and after treatment, indicating that these metals were not significant contaminants in the groundwater. This is a positive finding, as both metals are highly toxic even at low concentrations. The (Pb) concentration is in agreement with the findings of Opara *et al.*, [9] who investigated impact of auto-mechanic activities on groundwater in Diobu, Port Harcourt, Nigeria. The absence of these metals suggests that the groundwater source is not significantly impacted by lead-based paints or nickel-containing alloys commonly used in automobile workshops.

CONCLUSION

This study demonstrates that the treatment process effectively reduced heavy metal contamination in groundwater, with significant decreases in iron and copper concentrations. In addition, Lead and nickel were undetectable, indicating zero contamination from these metals. While pH, TDS, and conductivity remained within permissible limits, manganese levels exceeded the WHO guideline, emphasizing the need for further remediation efforts. The increase in COD and BOD after treatment suggests the presence of organic matter, warranting further investigation. Although the results indicate minimal impact of automechanic workshop activities on groundwater quality, there is a high likelihood that prolonged exposure could increase physicochemical and heavy metal concentrations, posing health risks to residents. To ensure long-term water safety, continuous monitoring, improved treatment strategies, and strict pollution control measures are recommended. Additionally, regulatory policies should be implemented to manage auto mechanic workshop activities in the area.

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